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Isopoda and Tanaidacea from Buoys in Coastal Waters of the Continental United States, Hawaii, and the Bahamas (Crustacea)[1]

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This article is based on collections made during World War II by the author and other biologists employed by Woods Hole Oceanographic Institution on a survey of marine fouling. The research was conducted under supervision of Dr. Alfred C. Redfield and the late Dr. Louis M. Hutchins. It was done under contract with the Bureau of Ships, U.S. Navy, with invaluable logistic support from the U.S. Coast Guard. The author wishes to express deep appreciation to Dr. Redfield for his guidance and encouragement on this and other wartime investigations on the marine fouling problem. The author is indebted to Mrs. Lynn Rudy for illustrations and other assistance in the preparation of this paper. Thanks are due also to Dr. Thomas E. Bowman of the U.S. National Museum for a critical review of the manuscript.

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Fouling communities include not only various sessile organisms (barnacles, mussels, bryozoans, tube worms, tunicates, sponges, algae, etc.) that attach themselves to submerged structures, but also many free-living forms associated with them. The free-living animals may feed on the sedentary forms, find cover among them, and exhibit various degrees of symbiosis with them. Among the nonsedentary forms commonly found in the fouling association are isopods, tanaidaceans, and other Crustacea.

The isopods and tanaidaceans reported in this paper were extracted from samples of fouling scraped from buoys and their moorings in the coastal waters of the United States. As mentioned above, these collections were made during World War II in connection with a survey of marine fouling conducted by Woods Hole Oceanographic Institution. Biological objectives included determination of the amount and kinds of fouling, rates of accretion, regional and seasonal variation, and ecological factors affecting establishment of fouling organisms. Much valuable systematic, ecological, and distributional data may be derived from investigations of this sort. Such information is needed badly for most invertebrate groups, especially in regions in which the biota has not been investigated adequately.

Besides intrinsic interest, the biological data also might have practical application in the development of more effective methods for control of fouling. Additionally, it was thought that data on buoy fouling could provide clues as to the origin and possibly the course of drifting mines and military flotsam. Cosmopolitan or widely distributed forms obviously would be of little or no value as tracers. Attached forms clearly would serve the purpose better than free-living types. In any event, the distributional limits of species that might be found on buoys would have to be established definitely before any valid conclusions could be drawn. Unfortunately, our present biogeographical knowledge of most invertebrates is too incomplete to be of much help in determining origin or drift.

The results of the marine fouling survey are incorporated in a treatise on marine fouling and its prevention that has been published by Woods Hole Oceanographic Institution (1952). The present paper extends the preliminary account of the Isopoda and Tanaidacea given in that publication.

Methods.—The buoy fouling survey was initiated in 1943. Biologists were assigned to various naval districts with authorization to accompany buoy tenders of the U.S. Coast Guard in order to investigate fouling on buoys when they were relieved, serviced, or otherwise tended. Generally, at this time, the buoy with mooring chain and anchor were hoisted onto the deck, which gave the biologists an opportunity for observation and sampling.

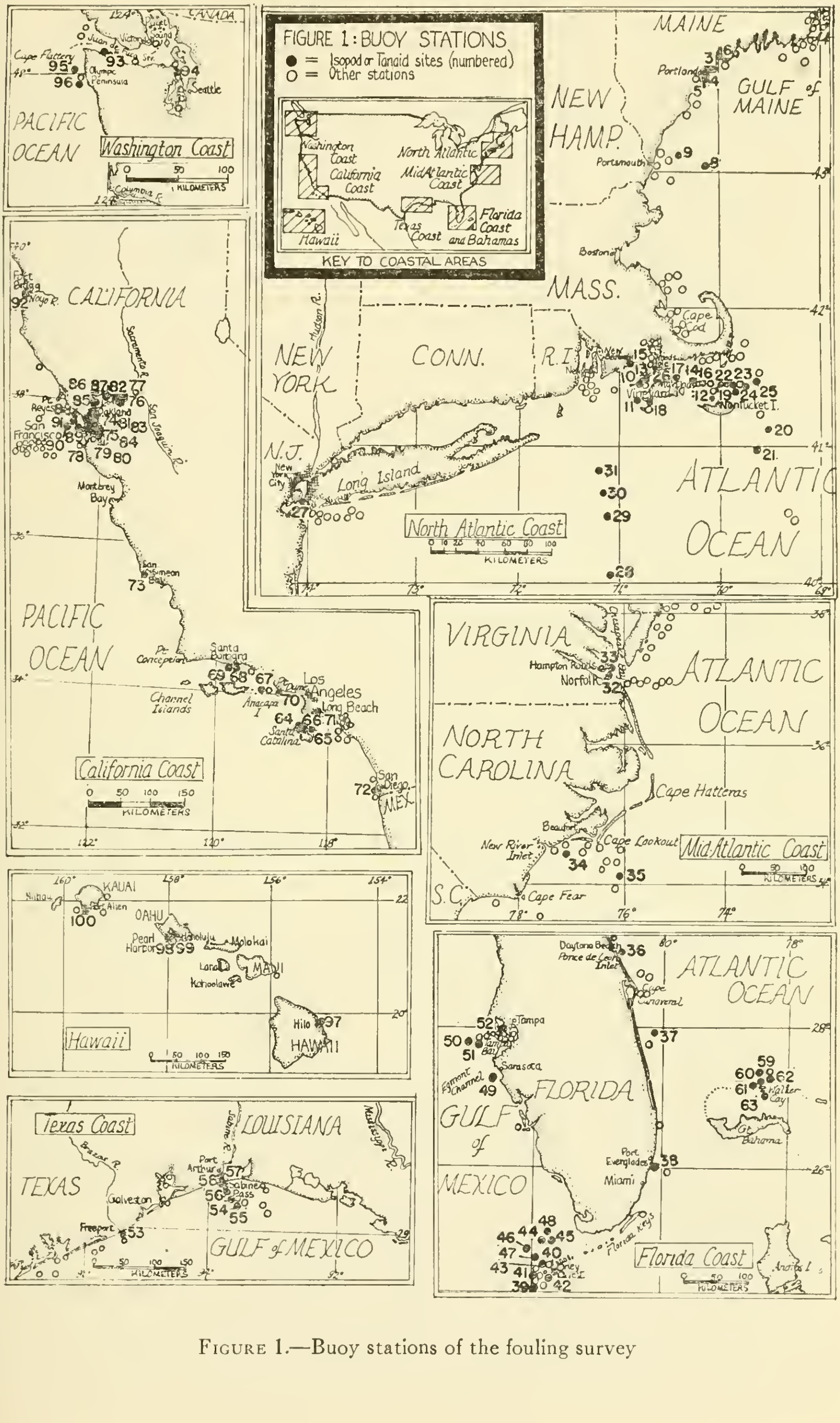

FIGURE 1.—Buoy stations of the fouling survey

The 379 buoys examined (fig. 1) were distributed as follows: 229 along the Atlantic coast from Newfoundland to Florida, 58 in the Gulf of Mexico (south and west coast of Florida and Texas), 77 along the Pacific coast from California to Washington, six in the Bahamas, and nine in the Hawaiian Islands. Owing to lack of opportunity for the biologists to sample the buoys along such a long stretch of coast, the largest gap in the collections lies between central California and northern Washington.

At each station, square foot samples were scraped from the buoy at the waterline, at three and six feet depths and subsequent fathom (6 feet=1.83 meters) intervals below the surface, depending on the size of the buoy. Linear foot scrapings also were made from the bridle and mooring chains at fathom intervals to the bottom. Likewise, a square foot sample was taken when possible from the anchor block. Occasionally, samples were taken from submarine nets or other submerged installations. After weights, volumes, and other data on the fouling were taken, the samples (or aliquots) were preserved and shipped to Woods Hole, Mass., for sorting. At each station, the usual hydrographic data were recorded (water temperature, transparency, etc.) and water samples for salinity determinations were taken.

At Woods Hole, the fouling samples were sorted into major taxonomic groups for later identification by specialists. After large organisms were removed, the residue was scanned with a microscope for small forms. A total of 2028 samples from 379 buoys were sorted, an average of five to six per buoy.

The 100 stations at which isopods and/or tanaidaceans were found are named in table 1. Their location is shown in figure 1, along with buoys in the same area at which none of these crustaceans was found.

Results.—Collection data are presented and summarized in tables 1 and 2 and figures 1 and 2. Isopods were taken from 95 buoys, or about one-fourth of the 379 sampled. Tanaidaceans were found on only 14 buoys, or 3.7 percent of those sampled. Five buoys yielded tanaidaceans but no isopods.

No isopods or tanaidaceans were found in the following vicinities (number of buoy stations sampled in each area in parentheses): Newfoundland (19); Eastport, Me. (12); Mt. Desert, Me. (13); Penobscot Bay, Me. (10); Delaware Bay (24); Chincoteague Bay, Va. (6); Cape Fear, N.C. (2); Cape Romain, S.C. (5); and Amelia Island, Fla. (6). Doubtless, both groups occur in these areas, perhaps even on buoys, but were missed in the sampling.

The collection comprises 26 species of Isopoda belonging to 16 genera distributed among seven families (fig. 2). These represent four of the seven aquatic suborders (Flabellifera, Valvifera, Asellota, and Anthuridea). The three suborders not represented are the Epicaridea,

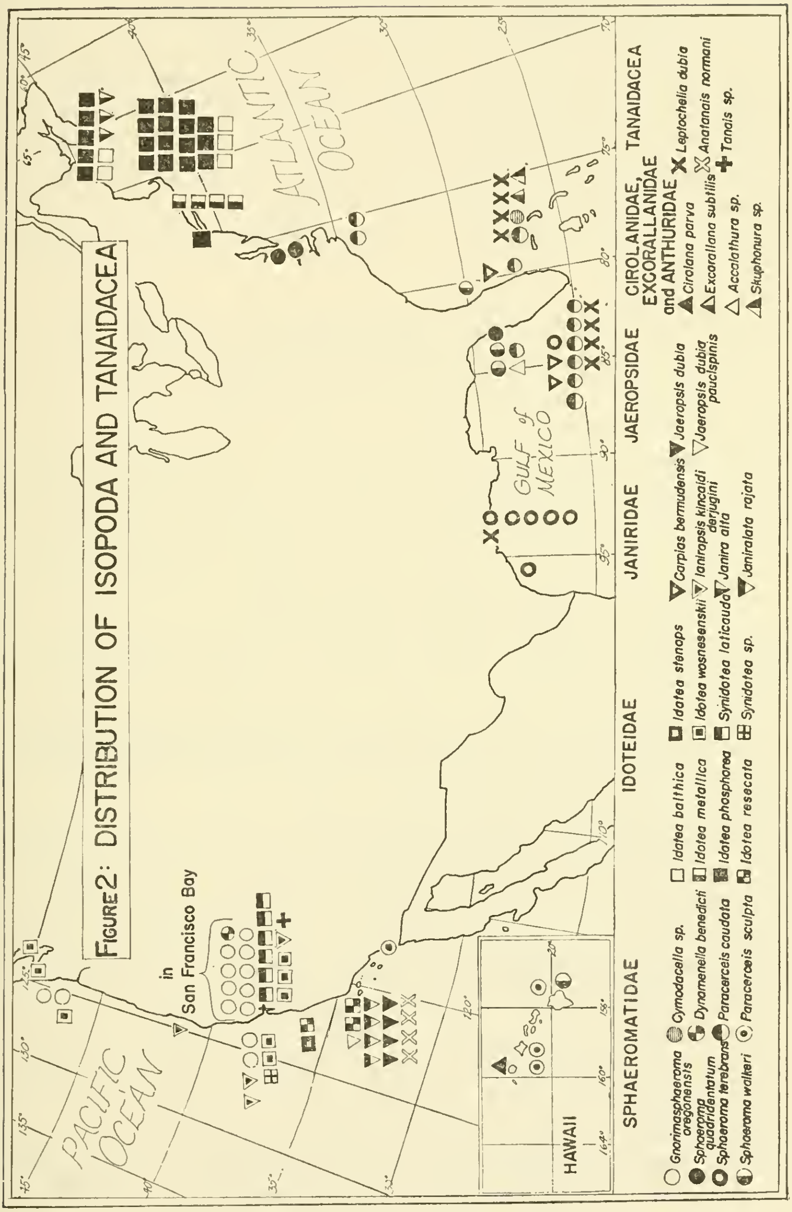

FIGURE 2.—Distribution of Isopoda and Tanaidacea on buoys.

Gnathiidea, and Phreaticoidea—the first parasitic on other Crustacea, the second ectoparasitic in the larval stage on fish, and the third found only in freshwater in Australia and South Africa.

The seven isopod families are represented unequally, both in numbers of species and in occurrences (table 2). To the total of 26 species, the Sphaeromatidae and Idoteidae contributed eight each, the Janiridae four, the Jaeropsidae and Anthuridae two each, and the Cirolanidae and Excorallanidae one each. The inequality is even more evident when the frequency of occurrence is considered with sphaeromids being found on 45 buoys, idoteids on 48, janirids on 13, jaeropsids on five, anthurids only on two, and cirolanids and excorallanids on one each.

The Tanaidacea are represented by only three species belonging to three genera and two families, Paratanaidae and Tanaidae. The one paratanaid species, the cosmopolitan *Leptochelia dubia*, was found on the Atlantic coast side; the two tanaids were taken on the Pacific coast.

The 29 species in the buoy collection were divided almost evenly by the continent—13 isopod species and one tanaidacean taken on the Atlantic side only (including the Gulf coast and the Bahamas), and 13 isopod species and two tanaidaceans taken only on the Pacific side (including one species found only in Hawaii). No species was found on both the eastern and western coasts, but the widely distributed *Sphaeroma walkeri* were found on buoys in Hawaii and Florida.

Of the 100 buoys from which isopods and tanaidaceans were taken, most (78) contributed only a single species. Two species were taken from 16 buoys, three species from five buoys, and four species from one (Station 48, Florida Keys region).

Considering depth occurrence (table 2), we note that 50 percent of records of capture of isopods (disregarding number of specimens) were within one meter of the waterline on buoys, and that about another 25 percent occurred between 1 to 5 meters from the surface. In the families Sphaeromatidae and Idoteidae, more than half of the records (53 percent and 55 percent, respectively) for each family are at 0 to 1 meter depth, and about three-fourths of their occurrences are within five meters of the surface. Janirids show the greatest range of occurrence, from 0 to 55.4 meters, with *Janira alta* being recorded at the greatest depth for all isopods (on the anchor block set at 55.4 meters depth). None of the Jaeropsidae, Cirolanidae, Excorallanidae, or Anthuridae was found within a meter of the surface, and none of the last three families named was taken at less than five meters of the surface. In fact, the single excorallanid and the two anthurids were taken from the anchor of buoys set at depths of 14.1, 11.1, and 15.4 meters. Tanaidaceans ranged from the surface to the bottom depths of 10 to 20 meters with the majority of occurrences (10 out of 18) below five meters and the median depth at which buoys were set. The number of species and the occurrences of tanaidaceans and of several isopod families are too small for more than cursory analysis. The possible relationship of motility with depth of occurrence will be discussed later.

In the following systematic review of the collection, the collection sites and previously reported localities for each species are given along with pertinent remarks on their systematics, ecology, and distribution.

Order ISOPODA

Suborder FLABELLIFERA

This sizable suborder (1400 species; Waterman and Chace, 1960) is represented in the fouling collection by 10 species belonging to seven genera distributed among three families—Sphaeromatidae (eight species), Cirolanidae (one species), and Excorallanidae (one species). Sphaeromatids were found on 45 buoys, but each of the other two families was taken from only one buoy.

Family SPHAEROMATIDAE

The sphaeromatids comprise a prominent group in the collection not only in number of species (eight), but also in the abundance of specimens. Swimming ability is relatively well developed in many members of this family, and this doubtless enables them to gain access to buoys. Woodboring sphaeromatids probably have been transported on wooden ship bottoms and in driftwood to new localities.

All the sphaeromatids in the buoy collection fall into two of the three "groups" in Hansen's (1905) subfamily Sphaerominae, namely the *hemibranchiatae* and *eubranchiatae*. The hemibranchiate genera are *Sphaeroma* (three species) and *Gnorimosphaeroma* (one species). The eubranchiate genera are *Paracerceis* (two species), *Dynamenella* (one species), and *Cymodocella* (one species). The *Sphaerominae platybranchiatae* are not represented.

Unfortunately, as Monod (1931b) remarked, the systematics of the Sphaeromatidae is in a state of confusion. The confusion stems from the tremendous sexual dimorphism in this family, coupled with parallel adaptations for conglobation. Females and immature males have been described as different species, even in separate genera, from adult males. Variation among individuals of the same size and sex adds to the taxonomic difficulties, as attested by long synonymies. Another complication, especially in widespread species, is that local races or subspecies probably have developed as a consequence of long geographic or ecological segregation of populations. There is also the possibility of hybridization between related alien and native species. Misidentifications, of course, distort the distributional picture; hence, authors should indicate the uncertainties in their determinations and their reasons for them. Such information also is valuable in systematic revision.

Group Hemibranchiatae

Sphaeroma quadridentatum Say

Figure 3

Localities.—Virginia: near Norfolk (Stations 32, 33). Florida: Tampa Bay (Station 52).

Remarks.—Richardson (1905b) lists *Sphaeroma quadridentatum* from many localities along the Atlantic seaboard from southern New England to Key West, Fla. Intermediate collection sites include waters in the vicinity of Cape Charles City, Va.; St. Catherine Island, Ga. (type-locality); and Beaufort, N.C. The buoys from which this species was collected lie within its known range. The available ecological data indicate that the species prefers muddy bottoms.

Nierstrasz (1917) reported this species from the Mediterranean, but Monod (1931b) lists the Mediterranean forms in the synonymy of *Sphaeroma serratum* (Fabricius) H. Milne Edwards. Earlier, Monod (1930) following Torelli (1930), also had equated *S. quadridentatum* from the east coast of North America with *S. serratum*. After examining topotypes of the former, however, he concluded that the two were separate species. He pointed out the following three distinctions: (1) In *S. quadridentatum*, there are four well-defined teeth on the outer border of the uropodal exopod, whereas the number of teeth varies in *S. serratum* (occasionally four) and they are often irregular crenulations, making it difficult to determine the precise number. (2) The posterior part of the telson in males of *S. quadridentatum* tends to be excavated dorsally with upturned borders, while in *S. serratum* it is vaulted more regularly. (3) In *S. quadridentatum*, there are fewer setae in the distal row on the propodus of pereopod I than in *S. serratum*. The buoy specimens confirm these observations.

Sphaeroma walkeri Stebbing

Figure 3

Localities.—Florida: Ponce de Leon Inlet (Station 36), Sarasota New Pass (Station 49), Egmont Channel (Station 51). Hawaii: Hilo (Station 97).

Remarks.—Previous reports indicate that *Sphaeroma walkeri* is widely but spottily distributed as follows. India: Gulf of Manaar (Jokkenpidd: Parr, Marichchukaddi, Cheval Paar, and Galle Harbour,

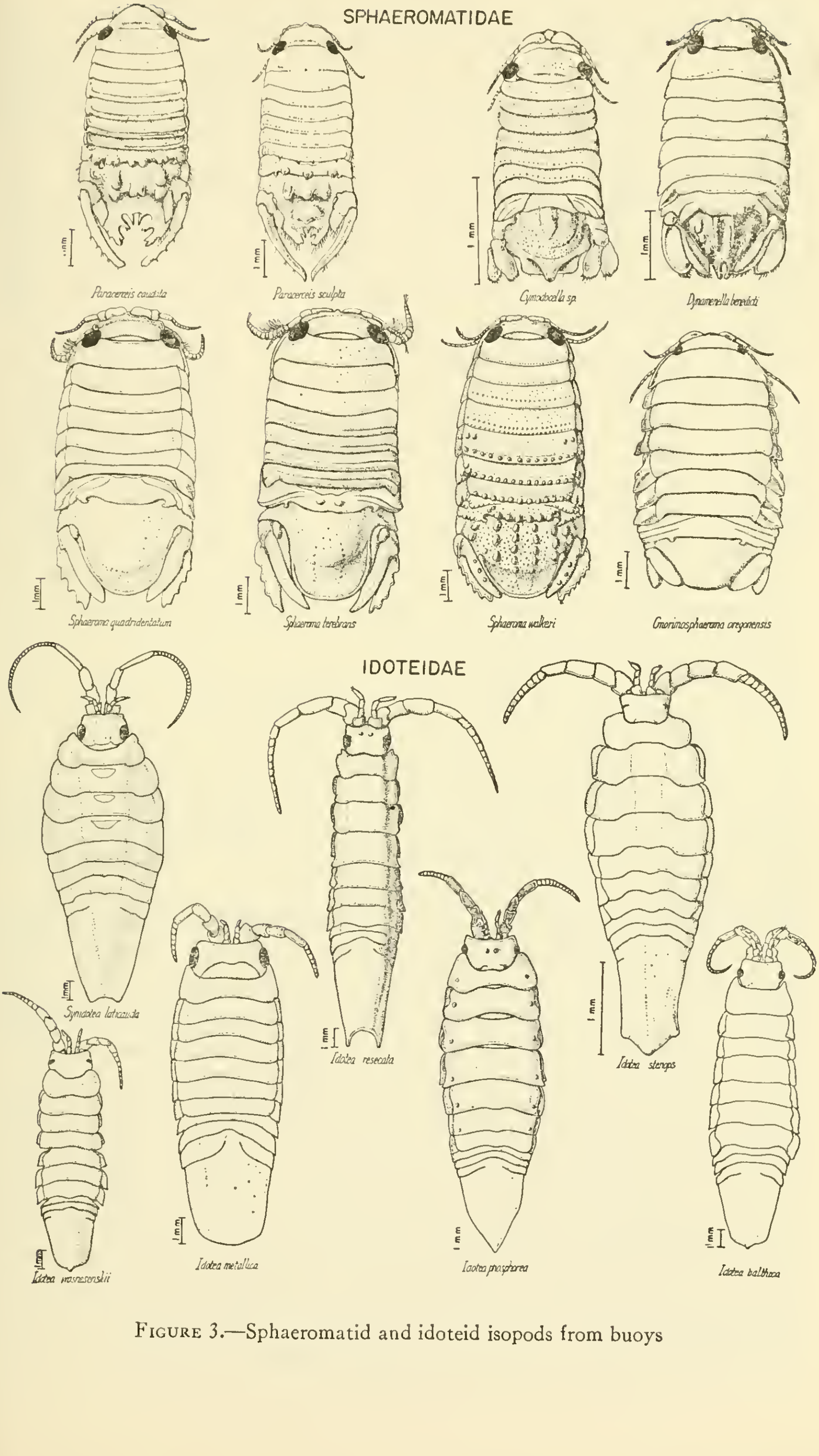

FIGURE 3.—Sphaeromatid and idoteid isopods from buoys

Ceylon—type-localities) (Stebbing, 1905); Travancore (Trivandrum) (Pillai, 1955); Bombay (Joshi and Bal, 1959). Red Sea and Suez Canal (Stebbing, 1910; Omer-Cooper, 1927; Monod, 1933). Africa: Egypt (Alexandria) (Larwood, 1940); Durban Bay (Stebbing, 1917; Monod, 1931b). South America: Brazil (Loyola e Silva, 1962). New South Wales: Blackwattle Bay, Darling Harbour (Baker, 1928).

With the addition of the above-listed localities in Florida and Hawaii, the recorded distribution of *Sphaeroma walkeri* is extended into the central Pacific and the northern hemisphere of the New World. Its spotty, circumglobal distribution and the fact that it has been taken from the hulls of boats (Larwood, 1940; Monod, 1933) strongly suggest dispersal by shipping.

Although the single specimen from Hilo was damaged badly, it was clearly conspecific with intact specimens collected by the author in August 1961 from Hanamaula Bay, Kauai, and no difference could be found between the Hawaiian specimens and those from Florida. The collection of specimens of *Sphaeroma walkeri* from two widely separated Hawaiian islands and from three localities on both the east and west coasts of Florida indicates that this species is fairly well established in these two regions. It would be of great interest to know when and how these isopods were introduced!

The identification of the buoy specimens as *Sphaeroma walkeri* seems certain, although there are some discrepancies between them and Stebbing's (1905) original description. At least they conform as well to his description as do sphaeromatids from other localities that have been assigned to that species by several authors. They show the distinctive pattern of tuberculation, the characteristic number of lateral teeth on the uropodal exopod, and the posteriorly dished telson with a rounded, upturned crenate border.

Our specimens differ from the original description of *Sphaeroma walkeri* primarily in showing epimeral sutures on the first as well as on the six subsequent pereonal segments. Stebbing states unequivocally that the "side plates" (epimera) of the first segment of pereon of this species are "unsutured." His figures, both dorsal and lateral views, agree with the text showing epimeral sutures on all but the first pereonal segment. Twelve years later, however, the same author (Stebbing, 1917) figures a male and female of this species from Durban Bay, South Africa, both lacking epimeral sutures on all seven pereonal segments. (Stebbing's 1910 report of this species from the Red Sea gives no description or figures.) The figures of *S. walkeri* from different localities given by other authors (e.g., Pillai, 1955) clearly indicate epimeral sutures on all pereonal segments including the first, as in our specimens.

One must conclude either that Stebbing did not attach any significance to epimeral sutures, or that the sphaeromatids from Durban Bay that he identified as his *Sphaeroma walkeri* might belong to a closely related species, possibly *S. venutissimum* Monod. The fact that his figures of these show other differences from the original description of *S. walkeri* lends credence to the latter view. For instance, the African specimens have tubercles on the head that are not indicated at all in his description or figures of the type. They also have eight or nine teeth on the uropodal exopod instead of the prescribed six or seven. (Although Stebbing's description of *Sphaeroma walkeri* states there are six or seven teeth on the outer margin of the uropod, his figures show only five. He doubtless counted as a tooth the pointed apex of the exopod.) It is difficult to believe that so eminent an authority as Stebbing could erroneously assign specimens to a species he himself described, albeit many years earlier.

Other differences between the buoy specimens and the description of *Sphaeroma walkeri* may be characterized as normal variation. Most specimens had five lateral teeth on the outer branch of the uropod (the typical number), but a few had four or six. Sometimes the number varied between the two sides of a specimen. Most had two tubercles on the dorsal side of the endopod, but several had three and one specimen had only one. The distinctness of the tuberculation, particularly on the thoracic segments, increases with the size of the specimen.

Sphaeroma terebrans Bate

Figure 3

Localities.—Florida Keys (Station 42). Texas coast: near Freeport (Station 53), off Sabine Pass (Stations 54–58).

Remarks.—The sphaeromatids from buoys off the Texas coast are assigned with some hesitation to *Sphaeroma terebrans*. This is a variable species widely distributed in warm waters (salt, brackish, and fresh) of both the Old and New Worlds (Nierstrasz, 1931; Van Name, 1936). Reported localities include many in India (Stebbing, 1904; Erlanson, 1936; Pillai, 1954); equatorial and southern Africa (Barnard 1920, 1940; Brian and Dartevelle, 1949; Stebbing, 1910); Australia (Baker, 1926; Calman, 1921; McNeill, 1932); Siam and Sumatra (Chilton, 1926); St. John's River (fresh water) at Palatka, Fla. (Richardson, 1905b); Escambia River, Fla., and Sabine River, Tex. (Wurtz and Roback, 1955); and Brazil (type-locality). Menzies and Frankenberg (1966) report it from Georgia, but as *S. destructor*. Dr. Thomas E. Bowman of the U.S. National Museum informs me (in litt.) that it also has been reported from Virginia by Wass (1963) but apparently was carried there on a ship from Florida. The above-cited Florida location is the type-locality of *S. destructor* Richardson, which has been considered a synonym of *S. terebrans* Bate by most authors despite Miss Richardson's stout defense for its distinctness. Her *S. peruvianum* from honeycombed wood in oyster beds in Peru and her *S. retrolaevis* from Japan are regarded as distinct from but closely related to *S. terebrans.*

As isopods of this species commonly are found burrowing in decayed wood, bridge and wharf pilings, dead mangrove roots, etc., dispersal by ships and driftwood seems a likely explanation for its widespread distribution. As with other widely distributed species, geographic and/or ecological segregation may result, in time, in reproductive isolation of local populations and subsequent speciation.

The specific identification of the Texas specimens is questioned primarily because the sculpturing of the dorsal surface, as far as this can be determined, does not conform entirely to the descriptions of this feature in *S. terebrans*. According to the descriptions, the dorsal surface on the posterior part of the body is covered with granules and tubercles of various sizes, the larger ones of which bear tufts of minute hairs, and there are tuberculated transverse ridges on the posterior thoracic segments. Well-developed paired tubercles are said to be characteristically present on the last one or two thoracic and on the two pleonal segments. The literature indicates, however, a certain amount of variation in sculpture pattern as well as in other characteristics.

Considerable individual variation in tuberculation was observed in the Texas specimens. The smaller ones were smooth, as in *S. quadridentatum*, or only minutely granular and transverse thoracic ridges were only slightly evident. Larger specimens usually were coated with mud, especially on the hinder part, which obscured the tubercles. Several previous authors mentioned the same difficulty with mud. In our specimens, the coating adhered so tightly that, when attempts were made to remove it, the underlying exoskeleton also peeled off. Nevertheless, it was possible to observe that our specimens had finely tuberculated transverse ridges on the posterior thoracic segments and tubercles on the pleon and pleotelson. Some specimens showed large paired tubercles on the pleon, others did not, and the pattern was not consistent. In some, there was evidence of two paramedian rows of tubercles on the pleotelson, as in *S. quoyana* M. Edwards.

Gnorimosphaeroma oregonensis (Dana) Menzies

Figure 3

Localities.—California: San Francisco Bay area (Stations 74–78, 80, 84–87, 91). Washington: Umatillo (Station 95), Quillayute River (Station 96).

Remarks.—This species, first described by Dana (1852) as *Sphae-*

roma oregonensis, subsequently has been placed in *Exosphaeroma*, *Neosphaeroma*, and currently, since Menzies (1954), in *Gnorimosphaeroma*. Menzies subdivided it into two subspecies, *G. oregonensis oregonensis* and *G. o. lutea*, but Riegel (1959) on the basis of morphological, physiological, and ecological evidence elevated the two subspecies to full species status.

Menzies states that *G. oregonensis oregonensis* ranges from Alaska to San Francisco Bay, Calif., with the type-locality in Puget Sound, Wash. He lists many records of distribution in this range. It occurs primarily in the intertidal zone to depths of 12 fathoms (20.8 meters) but has been taken at submerged night lights near the surface (Hatch, 1947; Menzies, 1954). It apparently tolerates in nature a wide range of salinities, as it was found on buoys in the upper reaches of San Francisco Bay (Suisun Bay, etc.) near the Sacramento-San Joaquin delta where salinities are low (oligohaline) and on buoys outside the bay and on the open seacoast outside the Golden Gate and along the coast of Washington.

Group Eubranchiatae

Paracerceis caudata (Say) Hansen

Figure 3

Localities.—North Carolina: Cape Lookout region (Stations 34, 35). Florida: Port Everglades (Station 38), Florida Keys (Stations 39–41, 44, 47, 48), Sarasota (Station 49), Tampa Bay (Station 50). Bahamas: Walker Cay (Station 62).

Remarks.—Richardson (1905b) records many localities for *Paracerceis caudata* (under the name *Cilicaea caudata*) ranging from Egg Harbor, N.J., southward to the Florida Keys, the Bahamas, Porto Rico, Yucatan, and the Bermudas. Reported depths are from the surface to 25 fathoms (46 meters) among algae and grass and from coral reefs. The buoy collections of this species are well within its previously recorded geographic and depth range. It appears to be predominantly a warm water species of the eastern North American coast.

Pronounced sexual dimorphism in this species results in taxonomic difficulty unless samples include mature males. Females alone are notoriously difficult to identify correctly and even have been described as distinct species (e.g., *Dynamene bermudensis* represents the female of *Paracerceis caudata*). Small females of *Paracerceis caudata* in the buoy collection, especially one from Satan Shoal Buoy (Station 39) near Key West, resemble the description of *Dynamene angulata* Richardson (1901). The latter was described only from female specimens found by Mr. Henry Hemphill at No Name Key, Fla. It has not been reported subsequently from any other locality. The possibility is suggested that, as in the above-cited case of *D. bermudensis*, *D. angulata* is also a junior synonym of *P. caudata*. The fact that Richardson (1905b) reported both *P. caudata* and *D. angulata* from No Name Key, however, indicates that she must have regarded these forms as distinct species. It would be inadvisable, therefore, to relegate *D. angulata* to the synonymy of *P. caudata* without critical comparison of Richardson's types with female and immature male specimens of *P. caudata* from the same region.

Paracerceis sculpta (Holmes) Hansen

Figure 3

Localities.—California: San Diego Harbor (Station 72). Hawaii: Hilo Harbor, Hawaii (Station 97); Pearl Harbor, Oahu (Stations 97, 98).

Remarks.—Richardson (1905b) reports *Paracerceis sculpta* from only two southern California localities, San Clemente Island and San Diego. In the author's collection there are specimens of this species collected by Marjorie Oakley Brown in Morro Bay, Calif. (unpubl. data), which is more than 200 miles north of the previous known range. The present records of this species in Hawaii greatly extend its distribution. Probably it was transported on the hulls of naval ships plying between San Diego and Hilo and Pearl Harbor.

Several other species of this genus occur along the Pacific coast, but none of these were taken in the buoy survey. One of these is a widely ranging species, *P. cordata* Richardson, which occurs along the Pacific coast of North America from Catalina Island, Calif., to Popoff Island and the Aleutian Islands. (There is a big gap in its recorded distribution, however, between the Alaskan localities and Mendocino County in northern California. Hatch, 1947, does not mention it in Washington and adjacent regions.)

Dynamenella benedicti (Richardson) Richardson

Figure 3

Locality.—California: South San Francisco Bay (Station 84).

Remarks.—Richardson (1905b) lists *Dynamenella benedicti* from Monterey Bay, Calif., its only recorded locality to my knowledge. The present record, therefore, extends its range considerably northward.

Cymodocella species

Figure 3

Locality.—Bahamas: Walker Cay (Station 61).

Remarks.—A single, small female sphaeromatid in rather poor condition is assigned with some uncertainty to the genus *Cymodocella*

Pfeffer. It possesses many of the attributes ascribed to the related genus *Dynamenella*, but the characteristic tubular posterior extension of the pleotelson with a slit along the underside places it in *Cymodocella*.

The generic placement is questionable, however, for several reasons. In Hansen's (1905) key to the *Sphaerominae eubranchiatae*, *Cymodocella* (as well as *Dynamenella*) falls into the section characterized by the exopod of the third pleopod being unjointed; but in the present specimen that structure is biarticulate. The apical tube is not as long as in other species of the genus. The rami of the uropod lamellar, as prescribed, and apically toothed, but subequal in length, whereas in typical *Cymodocella* the exopod is supposed to be considerably shorter than the endopod. Finally, because of the immaturity of the only specimen, the sexual characteristics of generic value could not be ascertained.

Five species of *Cymodocella* are known—the antarctic-antiboreal *C. tubicauda* Pfeffer and four African species from the Cape of Good Hope region; namely, *C. algoensis* (Stebbing) Stebbing, *C. cancellata* Barnard, *C. pustulata* Barnard, and *C. sublevis* Barnard. The facts that the present specimen does not fit the description of any of these and that it is the first record of the genus in the northern and western hemispheres indicate it may represent a new species. Pending examination of additional material—hopefully, mature specimens—of both sexes, it seems best to defer full and formal description.

Family Cirolanidae

The family Cirolanidae is represented in the buoy collections by a single specimen.

Cirolana parva Hansen

Figure 4

Locality.—Hawaiian Islands: Port Allen, Kauai (Station 100).

Remarks.—The family Cirolanidae is represented in the buoy collections by a single specimen of *Cirolana parva*. This species has previously been reported from many tropical localities including: Georgia (Menzies and Frankenberg, 1966); Florida, Gulf of Mexico, West Indies, and the Bahamas (Richardson, 1905b); Jamaica (Richardson, 1912); Cameroon and South Africa (Monod, 1931a, 1933); Mozambique (Barnard, 1914); Red Sea and Suez Canal (Stebbing, 1910; Monod, 1931 and 1933); Ceylon (Stebbing, 1905); Siam (Chilton, 1926); Polynesia: Rikitea (Nobili, 1907), Samoa (Hansen, 1890); Indonesia: Timov, Aru, et al. (Nierstrasz, 1931). The present report of this species in the Hawaiian Islands extends its distribution into the central Pacific. The author also has collected it from reefs around the islands of Kauai, Oahu, and Hawaii. The major gap in the near circumtropical distribution of this species is the eastern Pacific. Its absence there may be due merely to the fact that this area has not been explored sufficiently.

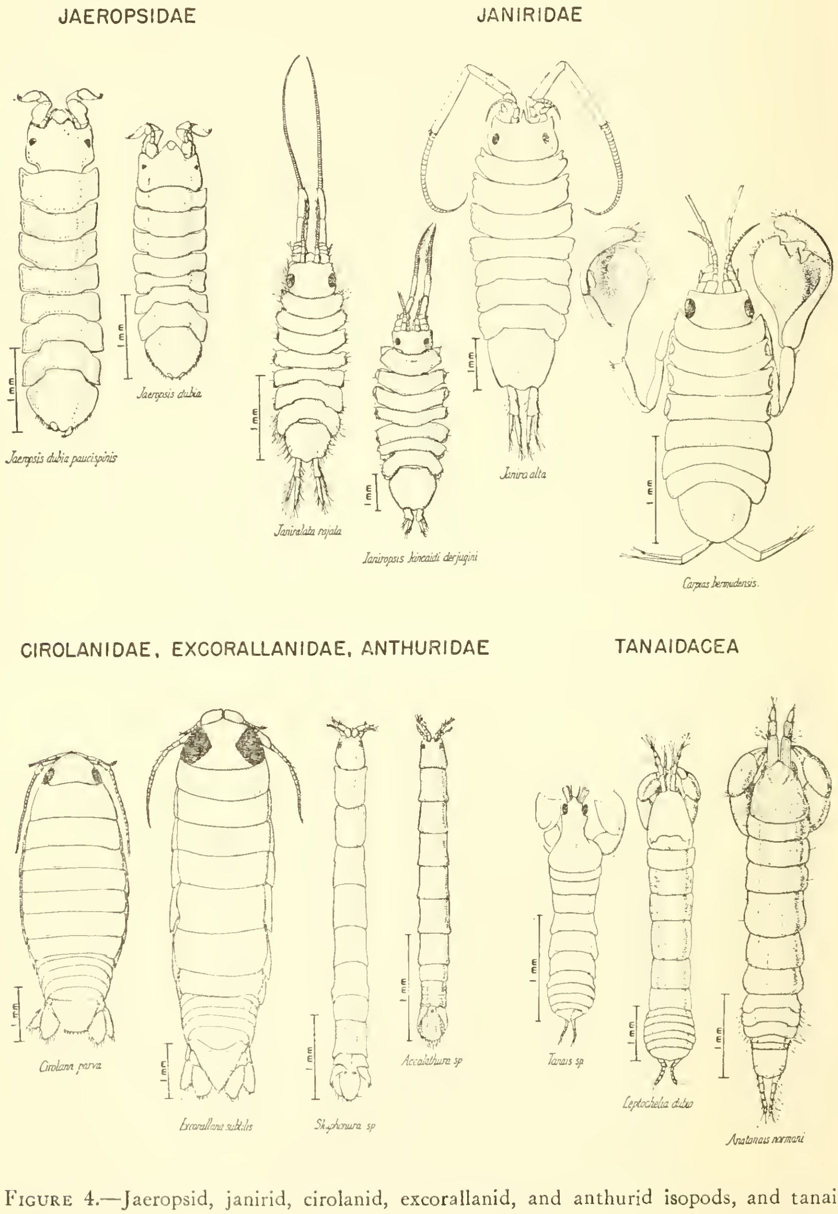

Figure 4.—Jaeropsid, janirid, cirolanid, excorallanid, and anthurid isopods, and tanaidaceans from buoys.

Family Excorallanidae

Excorallana subtilis (Hansen) Richardson

Figure 4

Locality.—Florida: Tampa Bay (Station 50).

Remarks.—Hansen (cited by Richardson, 1905b) records *Excorallana subtilis* from St. Thomas, West Indies. She also hesitatingly refers to this species two male specimens from Florida (specific locality not given) in the collection of the U.S. National Museum. These fit the description except for the lack of the two large tubercles at the base of the terminal abdominal segment. The specimen from Florida, an ovigerous female, agrees nicely with the description except that the two tubercles on the pleotelson are not as large as those figured by Richardson. Probably the presence and size of these tubercles are variable characteristics.

Suborder VALVIFERA

This suborder (containing some 600 species; Waterman and Chace, 1960) is represented in the collection by eight species, all in one family, taken from 48 buoys.

Of the two valviferan families known in North America, the *Astacillidae* (=*Arcturidae*) and the *Idoteidae,* only the latter is represented in the buoy collections. This family occurs mainly in the temperate zone and boreal zones, whereas astacillids are characteristic of still colder waters. Both families, however, have representatives in tropical or subtropical waters and the ranges of some extend into warm waters. Valviferans in general, however, are represented poorly in the tropics. In the buoy collections only one of eight idoteid species (*Idotea resecata*) was found south of 35° north latitude.

Family Idoteidae

Subfamily Idoteinae

Only two idoteid genera were found, both in the subfamily Idoteinae to which most idoteids belong: *Idotea,* with six species, and *Synidotea,* with two. The six species of *Idotea* were divided evenly between the Atlantic and the Pacific coasts. They probably are ecological equivalents. Both species of *Synidotea* were found on buoys along the Pacific coast. *Synidotea* is predominantly a North Pacific genus with only two circumarctic or circumboreal species known from the North Atlantic.

As previously mentioned, some idoteids, as well as sphaeromatids, are good swimmers, which accounts for their relatively greater frequency on buoys than the more sedentary isopods. Two species, *Idotea balthica* (=*marina*) and *I. metallica,* have been reported from widely separated localities in both northern and southern hemispheres.

Both species have been taken from floating seaweed, which suggests a possible means of dispersal.

Idotea phosphorea Harger

Figure 3

Localities.—Gulf of Maine (Stations 1–3, 5, 6). Nantucket Sound and vicinity (Stations 11–14, 16–26). New York area (Station 27).

Remarks.—Richardson (1905b) gives the distribution of *Idotea phosphorea* as "Coast of New England to Halifax, Nova Scotia, and the Gulf of St. Lawrence; Runmarõ, Stockholms Skãrgõrd," at depths from the surface to 18 fathoms (about 33 meters), among seaweed, and in the stomach of haddock. In the present study, it was taken from 21 buoys from New York to the Gulf of Maine, all within its previously recorded range.

Generally found within three meters of the surface, it also was taken at various depths down to about 23 meters. On one buoy (Station 23), more than 35 specimens were taken. This species was found on the greatest number of buoys in the entire collection.

Idotea balthica (Pallas)

Figure 3

Localities.—Gulf of Maine (Stations 4, 5). Nantucket Sound (Stations 10, 15, 18).

Remarks.—The nomenclature of this widely distributed and doubtless variable species has had a controversial history. The name *Idotea marina* (L.) has appeared in the literature both as a junior and senior synonym of *I. baltica* (Pallas) (also spelled "*balthica*," the original spelling of Pallas). Holthuis (1949) reviewed the case and concluded that *I. marina* was correct. He later (1956) reversed himself, however, apparently persuaded by the arguments of Naylor (1955). Hurley (1961) transfers the New Zealand records of *I. baltica* to *I. marina*. Gruner (1965) uses *I. balthica* [sic] and lists among its synonyms *I. marina* of Richardson (1905b) and Holthuis (1949). He does not mention Hurley (1961) but says that the question of occurrence of *I. balthica* [sic] in New Zealand (as well as Java, Brazil, and the Red Sea) must be reexamined.

Richardson's (1905b) list of localities (given below) for *Idotea baltica* (Pallas) is essentially similar to her earlier list (1901) for *I. marina* (L.) in which the former was included among other synonyms. Both her lists incorporate the distributions given by Miers (1883), Harger (1873), and previous authors. Richardson's (1905b) list is as follows:

> Atlantic coast from Nova Scotia and Gulf of St. Lawrence to North Carolina; Bermudas; Barbados; also Mediterranean, Black and Caspian seas; west coast of Europe to Great Britain; shores of the Netherlands; in German Ocean and

Baltic Sea; Bohusland, Sweden (W. Sachs); Runmarö, Stockholms skärgård (J. Lindahl); on Scandinavian and Finland coasts; South America, at Desterro and Rio Janeiro, Brazil; New Zealand; Red Sea; Java.

Hansen (1916) considers Richardson incorrect in listing this species from Brazil, New Zealand, the Red Sea, and Java. He contends that these localities were listed by Miers (1883) for *I. marina* and under that name Miers "had mixed up at least four and probably five or six species." As previously mentioned, Gruner (1965) also considers these locality records questionable.

Idotea balthica (=*baltica*=*marina*) subsequently has been reported by many authors from many localities: North Sea (Zirwas, 1910); Iceland and the Faroes (Hansen, 1916); Ireland (Tattersall, 1912); Great Britain (Naylor, 1955); the Netherlands (Koumans, 1928; Holthuis, 1949, 1956); Alexandria, Egypt (Larwood, 1940); Australia (Hale, 1924), New Zealand (Hurley, 1961); New Guinea (Nierstrasz and Schuurmans Stekhoven, 1941).

Gruner (1965) summarizes localities mentioned by previous authors and recognizes several subspecies: *Idotea balthica balthica* Dahl (Baltic Sea), *I. b. tricuspidata* Dahl (North Sea), *I. b. basteri* Audouin (Mediterranean), and *I. b. stagnea* Tinturier-Hamelin (Mediterranean, on the coast of Roussillon).

Richardson (1905b) gives depths for *I. baltica* from the surface to 119 fathoms (220 meters) and states it has been found on floating seaweed, among algae and eelgrass, in sand and gravel, and from the stomachs of smelt. Zirwas (1910) found it on floating wood or algae. Hansen (1916) states depth records are misleading as "the animals, which can swim rather well and frequently live among floating algae, have been taken in the instrument when it was hauled up." Gruner (1965) states that this species is euryhaline, sometimes found in water with salt concentrations as low as 3.5 ‰. It is sublittoral, usually does not go deeper than 20 meters, but has been found at depths of 340 meters. In the present study, this species was found on five buoys, all in the New England region, always within a meter of the surface.

Idotea metallica Bosc

FIGURE 3

LOCALITIES.—New York area (Stations 28–31).

REMARKS.—*Idotea metallica*, a widely distributed, nearly cosmopolitan species, has been reported from many localities including the Atlantic coast from Florida Keys to Nova Scotia, Greenland, Iceland, Britain, Ireland, Mediterranean Sea, Indian Ocean, northwestern Australia, New South Wales, New Zealand, Sumatra, Borneo, Sea of Japan, Cape of Good Hope, Antarctic, Montevideo, Straits of Magellan, Chile, and Patagonia (Richardson, 1905b, 1909; Gurjanova, 1936; Dow and Menzies, 1957; Naylor, 1957; Nordenstam, 1933; Thielemann, 1910; Hurley, 1961; Menzies, 1962; Hansen, 1916).

Reported depths for *Idotea metallica* are from the surface to 91 fathoms (166 meters). It has been found on floating fucus. Dow and Menzies (1957) report this species (forma *typica* Cărăușu) as commonly taken in surface plankton tows in the Mediterranean. Their analysis of stomach contents indicates its food consists principally of brown algae, possibly *Sargassum*. They conclude that this form is a pelagic surface-dwelling isopod. Their conclusion is supported by the present study as all specimens of this species were taken at the surface level on four buoys set in open and relatively deep water (59–76 meters) at some distance (50–100 or more kilometers) east of Long Island and south of Massachusetts.

Idotea (Pentidotea) resecata (Stimpson) Menzies

FIGURE 3

LOCALITIES.—California: Anacapa Island (Station 67), Santa Barbara (Station 69), San Simeon (Station 73).

REMARKS.—*Idotea resecata* ranges from southern California to Alaska (Richardson, 1905b; Hatch, 1947; Menzies, 1959) with many localities reported along the coasts of California (San Pedro to Humboldt Bay), Washington, and British Columbia. The author has collected specimens of this species at Los Coronados Islands off San Diego, a locality that extends its known range considerably southward.

According to Richardson (1905b), it is found between tide marks among rocks, seaweed, kelp, eelgrass, etc. at depths from surface to 3.5 fathoms (about 6.4 meters). Dow and Menzies (1959), however, consider it as the Pacific Ocean counterpart of *Idotea metallica*, a truly pelagic species.

The buoy collections of *Idotea resecata* were well within its recorded range of distribution, which extends several thousand miles along the Pacific coast of North America from subtropical to boreal waters. This species apparently has a wide temperature tolerance.

Idotea (Pentidotea) wosnesenskii (Brandt) Menzies

FIGURE 3

LOCALITIES.—California: San Francisco Bay area (inside the bay: Stations 75, 81, 84; outside: Stations 88, 89). Washington: Strait of Juan de Fuca (Station 93), Puget Sound (Station 94), outer coast at Quillayute (Station 96).

REMARKS.—*Idotea wosnesenskii* is common in temperate and cold waters along the entire Pacific coast of North America from central California to Alaska and in the Bering Sea, Sea of Ochotsk, and Kamchatka Sea (Richardson, 1905b; Thielemann, 1910; Gurjanova, 1936; Nierstrasz and Schuurmans Stekhoven, 1941; Hatch, 1947). Richardson (1905b) gives its southern limit as Monterey Bay, Calif., but Thielemann (1910) states it occurs as far south as San Diego. Menzies and Barnard (1959), however, do not list it among the marine isopods of the southern California coastal benthos. The author has specimens from San Simeon, some 100 miles north of Point Conception, which divides the warm water coastal fauna of southern California from the colder water fauna of central and northern California.

Richardson (1905b) records depths from the surface to 9 fathoms (16.4 meters). It is found commonly on kelp exposed at low tide. On buoys, it was found generally at or near the waterline.

Idotea (Pentidotea) stenops (Benedict) Menzies

Figure 3

Locality.—California: San Simeon Bay (Station 73).

Remarks.—*Idotea stenops* has been reported from Monterey Bay, Calif. (Richardson, 1905b); Coos Bay, Oreg. (Hatch, 1947). The author has collected it among algae in the low intertidal zone at several localities along the central California coast from Moss Beach (San Mateo County) to Stockhoff Cove (Sonoma County).

No depths are reported in the literature for this species. On the buoy at San Simeon, it was found at the surface with *Idotea resecata.*

Synidotea laticauda Benedict

Figure 3

Localities.—California: greater San Francisco Bay (Stations 76, 79, 82, 83, 87).

Remarks.—The distribution of *Synidotea laticauda* is limited to greater San Francisco Bay, with localities recorded in all three divisions—southern (lower), middle (central), and northern (upper) divisions (Richardson, 1905b; Filice, 1958; author's collection). The northern division includes San Pablo Bay, Carquinez Straits, and Suisun Bay as far inland as Pittsburg near the mouth of the Sacramento-San Joaquin River delta. It has never been collected on the open coast outside the bay.

On buoys, *Synidotea laticauda* was taken at various depths from the surface to 7.4 meters. Richardson (1905b) records it at 12.3 meters. On several buoys, large numbers of these isopods were taken feeding on hydroids *Bimeria franciscana* Torrey.

Many environmental factors, alone or in combination, doubtless limit the distribution of this species to San Francisco Bay. Prominent among these are salinity, temperature, turbidity, oxygen content, and tidal and river currents. Quite as important ecologically as average conditions with regard to these factors are the fluctuations and extremes. Special conditions are created by the geography of this bay system, which features a narrow entrance (Golden Gate), two long narrow divisions extending northward and southward from the middle section, and the combined discharge into the northern arm of two major rivers—the Sacramento and San Joaquin. In addition to mechanical effects, the complex interaction of the inflow of these and lesser rivers and streams with the diurnal ebbing and flooding tides through the Golden Gate results in significant fluctuations, especially in salinity and temperature.

Salinities at the localities for this species range from polyhaline to oligohaline. At Fort Point, at the Golden Gate entrance to San Francisco Bay and less than a mile seaward from Station 83 (Crissy Field Buoy), salinities average 30–31 °/₀₀. From there, average salinities decrease progressively inland to about 27–29 °/₀₀ in the middle southern division and to about 25 °/₀₀ at the southern end of San Pablo Bay, to 15–16 °/₀₀ at Crockett at the seaward end of Carquinez Straits, to 10 °/₀₀ at Martinez at the other end of the straits, to 1 °/₀₀ at Pittsburg, and to 0.3 °/₀₀ at Antioch (Miller, et al., 1928; Filice, 1954).

As to temperature, the study of Miller, et al. (1928), conducted in July 1923, indicates that the lowest average surface temperatures are found at the entrance to the bay (14.1°C at Fort Point) with increases to 17.8°C at Oakland in the middle bay, to 20.6°C at Dumbarton Bridge in the southern part, and to 19.1°C at Crockett in the northern arm.

As to other factors, turbidity is relatively high at the two ends of the bay system, especially at the northern end owing to silt from the rivers. Toward the mouth of the bay, the water becomes clearer with turbidity normally negligible at the Golden Gate. As might be expected, oxygen content is higher in the colder, less polluted water at the bay entrance. In the upper bay, it is almost invariably below the saturation point (Filice, 1954). Filice could find no evidence, however, that there was a correlation between depressed oxygen values and the presence of wastes, or that the amounts of oxygen present affect the bottom fauna in any way.

Judging from environmental conditions at the various collection sites in San Francisco Bay, I conclude that *Synidotea laticauda* is able to tolerate a wide range of salinities, temperature fluctuations, turbidity, and other estuarine conditions. I will present evidence in a forthcoming paper (with R. J. Menzies) that it probably is a relict of a warm water species that occurred in the bay region in earlier times when warm waters extended far northward along the Pacific coast.

***Synidotea* species**

LOCALITY.—California: San Francisco Bar Channel (Station 90).

REMARKS.—One specimen too badly damaged for positive specific identification was taken from the buoy chain at a depth of 14.8 meters.

It is probably *Synidotea bicuspida* (Owen), as this is a widely distributed cold water species found along the Pacific coast as far south as San Francisco Bay, on the Atlantic coast as far south as Labrador, in the Arctic Ocean, and in the Sea of Japan. It has been collected frequently both inside and outside of San Francisco Bay.

Suborder ASELLOTA

The Asellota (comprising 500 species; Waterman and Chace, 1960) were represented in the buoy collections by six species (including one subspecies) in five genera, belonging to the two families, Janiridae and Jaeropsidae. Two janirid species in separate genera were found on Atlantic coast buoys; three species and one subspecies in three genera were taken from Pacific coast buoys.

Family JANIRIDAE

This family contains 35 genera and 136 species, evenly distributed around the world with three-fifths of the species restricted to the continental shelves (Wolff, 1962).

Janira alta (Stimpson) Harger

FIGURE 4

LOCALITIES.—Gulf of Maine (Stations 7–9).

REMARKS.—Richardson (1905b) reports *Janira alta* from the following localities: "Long Island; Massachusetts Bay, near Eastport, Me.; Gulf of Maine; Grand Menan; Bay of Fundy; 120 miles south of Halifax; Grand Banks; Clarke's Ledge; 30 miles east of Sable Island; off Chesapeake Bay." Hansen (1916) reports it as taken by the *Ingolf* at a single station west of Iceland. Richardson (1905b) records depths of 35 to 487 fathoms (64–886 meters), but Wolff (1962) gives a range of 0 to 1384 meters. In the present study, specimens were taken at 40 and 55.4 meters. Apparently it ranges into moderately deep water in the northern and western Atlantic. The buoy collections are well within its recorded range.

Carpias bermudensis Richardson

FIGURE 4

LOCALITIES.—Florida: east coast (Station 37); Key West region (Stations 45, 48).

REMARKS.—Previously reported only from the Bermudas (Richardson, 1902, 1905b), *Carpias bermudensis* was found at three stations off the coasts of Florida. This extension of its known range is not surprising in view of the affinities of Carribbean and Bermudan faunas. It will likely be found elsewhere in the Antilles. Indeed, it probably originated there and was carried northward to Bermuda by the Gulf Stream. In Bermuda, it occurs in shallow water on submerged reefs, among corals, etc. On one buoy (Station 37) it was found on the anchor at 14.8 meters, but on two others it was found only 1.5 and 2.2 meters from the surface in water 13.8 and 11.1 meters deep, respectively.

Males of this species are distinctive having elongate first pereopods (gnathopods) with distally expanded carpus and propodus, each provided with opposing triangular processes. Females (and immature males) lack this modification of the first leg and superficially resemble females of many other janirid species.

Janiralata rajata Menzies

FIGURE 4

LOCALITIES.—California: Catalina Island (Stations 64, 66); Anacapa Island (Station 67).

REMARKS.—Menzies (1951) described this species from a male specimen in the U.S. National Museum (USNM 43646) that had been collected at Monterey Bay, Calif., by Harold Heath from an egg of *Raja binoculata* at a depth of 20 fathoms (36.4 meters). Deeming its previous identification as *Janiropsis californica* by Richardson to be in error, Menzies redescribed it as a new species assigned to his new genus *Janiralata*. It is known only from the type-locality, Monterey Bay. Thus, the present collection greatly extends its known range.

Menzies (1951) established the genus *Janiralata* with 10 species, including eight transferred from other genera (three from *Janira*, five from *Iolella*) and two new descriptions. Of these, Menzies and Barnard (1959) list two as occurring in southern California, namely, *J. occidentalis* (Walker) and *J. solasteri* (Hatch). The present report adds a third from that region. Kussakin (1962) recently has described six new species, all from the northwest Pacific. He also transfers two other species to *Janiralata*, namely, *Janira tricornis* Krøyer and *Iolella chuni* Thielemann. All known species of *Janiralata* occur in the Pacific except *J. tricornis*, which occurs off Greenland, off Franz Josef Land, and in the Bering Sea. The latter locality is added because Kussakin assigns *J. alascensis* (Benedict) to the synonymy of *J. tricornis* (Krøyer).

Ianiropsis kincaidi derjugini (Gurjanova) Menzies

FIGURE 4

LOCALITIES.—California: Alcatraz Island, San Francisco Bay (Station 81); Coast off San Francisco (Stations 88, 89); Noyo River (Station 92).

REMARKS.—Menzies (1952) gives the distribution of *Ianiropsis kincaidi derjugini* as Komandorskie Islands, Bering Sea, to Monterey County, Calif. He states that this subspecies is found under rocks in the middle and lower intertidal zones, whereas the other subspecies, *I. k. kincaidi,* occurs in small pools where the water is supplied by wave splash and is subject to extremes in temperature. The buoy collections of *I. k. derjugini* are within its recorded geographical range. It was taken from buoys at depths from the surface to 1.8 meters.

Of the 17 described species (including subspecies) of *Ianiropsis,* seven occur on the Pacific coast. Of these, five are known only from the central California coast.

Family JAEROPSIDAE

Jaeropsis dubia Menzies and *J. d.* var. *paucispinis* Menzies

FIGURE 4

LOCALITIES.—*Jaeropsis dubia:* California: Catalina Islands (Stations 64–66), Point Dume (Station 70). *Jaeropsis d. paucispinis:* California: Los Angeles Harbor entrance (Station 71).

REMARKS.—Menzies and Barnard (1959) give the distribution of *Jaeropsis dubia* and its variety *paucispinis* as Marin County, Calif., to the Mexican border. The author's collection contains specimens of this species collected by Lloyd Tevis at Bahia del Tortuga, Mexico, north latitude 27°40′, which extends its known range considerably south of the border; hence, the present records are well within this range.

Menzies and Barnard (1959) state that it occurs at depths of 10 to 50 fathoms (18.2–91 meters) but usually at less than 30 fathoms (54.6 meters), associated with algae. They further state that, at depths greater than 30 fathoms, these forms are located in clear water since, in turbid waters, algae rarely are collected below 20 fathoms. In the buoy collections, *J. dubia* was collected at depths ranging from 1.8 to 13 meters, and *J. d. paucispinis* at 5.5 meters. The former was taken in areas with rocky bottom, the latter from an area with sand-shell bottom.

Neither Menzies (1951) nor Menzies and Barnard (1959) indicates any ecological segregation of the two entities, both being collected together in the same localities. The variety is separated solely on morphological grounds, namely, fewer spines on the lateral border of the pleotelson and possibly color pattern. Both are related closely to *Jaeropsis lobata* Richardson described from Monterey Bay, Calif. That species is perfectly smooth, however, lacking spines on the pleotelson and fringed scales on the frontal lamina and antennae, and it has a distinctive color pattern.

Suborder ANTHURIDEA

Only two specimens of this small suborder (only 100 species; Waterman and Chace, 1960) were found in the entire buoy collection, one from the west coast of Florida, the other from the Bahamas. They belong to the same family but in separate genera. The poor representation of anthurids in the fouling samples can be attributed mainly to their benthic mode of life. Both were taken in scrapings from the buoy anchor.

Family ANTHURIDAE

Skuphonura species

FIGURE 4

LOCALITY.—Florida: west coast (Station 48).

REMARKS.—The single female specimen conforms in many important particulars to the description of *Skuphonura laticeps* Barnard (1925a), the type and only known species of the genus. It was described from specimens collected at St. Thomas, St. John, St. Croix and Tobago, West Indies, at depths of 4 to 20 fathoms.

The generic assignment seems fairly certain. Among the characteristics placing it in the genus are: (1) the conformity in mouthparts, notably maxillipeds with four free joints; (2) the complete fusion of the anterior five pleonic segments; (3) the pereopods with the fifth joint of pereopods IV–VII underriding the sixth joint; (4) the thin, subovate telson with paired statocysts; and (5) the nonindurated uropod with exopods not folding over telson. The major differences from the generic description are: (1) the unsutured part of the pleon is nearly as wide as but not wider than the pereon; (2) the sixth (free) pleonal segment is not narrower than the preceding segments; and (3) the flagellum of the second antenna is pauciarticulate, rather than uniarticulate. Since the genus is monotypic, it is not unreasonable to assume that some of the ascribed generic characteristics with which the present specimen differs may prove to be only specific traits when additional species are described. The generic description may be emended accordingly.

Among the specific characteristics of *S. laticeps* shown by our specimen are: (1) a strong, forward-directed, medioventral spine on the first pereonal segment; (2) pereon strongly keeled ventrally; (3) antennae shorter than head; (4) first pereopod with fifth joint apically produced and unguis narrower than finger; (5) uropod with endopod about twice as long as broad with apex subacute and setose, and exopod apically notched, crenulate, and setose. Our specimen differs, however, from the description of *S. laticeps* in the following respects: (1) the anterior part of the head is not expanded laterally; (2) the eyes hardly can be described as small with some 22 ocelli on the dorsal, lateral, and ventral sides of the head; and (3) the palm of the first pereopod bears a low, blunt tooth.

Since the description of this species is based primarily on the male and the only specimen is a female, the character of the second pleopod can not be compared; moreover, it may be that some of the above-mentioned differences (both specific and generic) may be due merely to sexual dimorphism. Barnard (1925a), for instance, indicates that the head is less expanded in the young, which one also might assume to be the case in females.

The alternatives implicit in the foregoing discussion are (1) to identify the lone specimen as the female of *Skuphonura laticeps* Barnard, (2) to describe it as a new species of *Skuphonura* with an emended diagnosis of the genus, or (3) to identify it only to genus. The first alternative would result in a considerable extension of geographic range of *S. laticeps*, which is ecologically plausible since both occur in warm waters. The second possibility does not seem feasible at this time with the material available; it easily could result in an addition to synonymy. The third possibility seems to be the best decision in this case, leaving the opportunity open for action on the other two when more material is at hand.

Accalathura species

FIGURE 4

LOCALITY.—Bahamas: Walker Cay (Station 59).

REMARKS.—The second of two anthurid species in the buoy collections is represented by a small (3.5 mm) immature specimen that is assigned tentatively to the genus *Accalathura* Barnard (1925a). Its immaturity is indicated by its small size and the presumably incomplete development of the seventh pair of pereopods, which are about half the length of the sixth pair. This makes its determination uncertain and incomplete.

The generic assignment is based on the following characteristics: an unpaired statocyst at the base of the telson; a relatively short, distinctly segmented pleon; the fifth joint of the posterior pereopods not underriding the sixth; and a 4-jointed maxilliped. There are several discrepancies, however, between the generic description and the specimen, probably associated with its immaturity; for instance, the flagella of the first and second antennae are uniarticulate and pauciarticulate, respectively, rather than both being multiarticulate.

It has not been possible to identify our specimen with either of the two species of *Accalathura* known to occur in the Antillean region, namely, *A. crenulata* (Richardson) and *A. crassa* Barnard. *Accalathura crenulata* has been reported from the Bahamas and other tropical Atlantic localities (Yucatan, Brazil, Danish West Indies, and Cape Verdes) at depths of 5 to 40 fathoms (9–72 meters); *A. crassa* is known only from St. John, West Indies. The presence of well-developed eyes in this specimen distinguishes it from *A. crassa*, in which eyes are absent. The present specimen differs from the descriptions of *A. crenulata* in several details, although many (if not all) of the variances may be due to age. The buoy specimen is only 3.5 mm in length, whereas Barnard's (1925a) description of *A. crenulata* gives a length of 18 mm. The buoy specimen also differs from the description of this species in lacking crenulations in the telson, in showing only slight crenulations on the margin of the uropodal exopod, in having a more broadly rounded telson, and in having the posterolateral angles of the seventh pereonal segment only slightly produced backward.

Order TANAIDACEA

As previously indicated, the Tanaidacea (Chelifera) are represented poorly in the buoy collection. Only three species in as many genera were encountered, two in the family *Tanaidae* G. O. Sars (as emended by Lang, 1949) and one in the family *Paratanaidae* Lang, 1949. They were found on only 14 buoys. Although this is a relatively small order (only 250 species; Waterman and Chace, 1960) compared to the Isopoda (4000 species), tanaidaceans are taken commonly in benthic samples, especially in warm waters. Except for one station in San Francisco Bay, Calif., the buoys from which tanaidaceans were collected were situated in warm coastal waters of the Bahamas, Florida, Texas, and southern California.

Suborder DIKONOPHORA

Family PARATANAIDAE

Leptochelia dubia (Krøyer) G. O. Sars

FIGURE 4

LOCALITIES.—Bahamas: Walker Cay (Stations 59, 60, 62, 63). Florida: Key West region (Stations 43, 46–48). Texas: Sabine Pass (Station 58).

REMARKS.—Conflicting views regarding the synonymy of *Leptochelia dubia* and related species make it difficult to define its geographic distribution.

Richardson (1905b) gives only three localities for *L. dubia:* Brazil, Bermudas, and "Porto Rico." Her earlier list (1901), however, also includes several other localities: Noank, Conn.; Woods Hole and Provincetown, Mass.; Guernsey, British Channel; Ireland; Atlantic coast from Brittany to Senegal and Teneriffe; and the Mediterranean. The discrepancy is due to Richardson's transferring several names from the synonymy of *L. dubia* to that of *L. savignyi* (Krøyer) and incorporating their recorded localities in the list for the latter. It is pertinent to the later discussion to note that Richardson (1901, 1905b) regards *L. dubia* and *L. savignyi* as distinct species although the only recognizable difference is in the number of articles in the inner branch of the uropoda, the former having five joints, the latter six.

Monod (1933) regards *L. lifuensis* Stebbing as a junior synonym and concludes that *L. dubia* is a tropical and subtropical cosmopolite. Larwood (1940), however, goes further by adding *L. savignyi*, *L. algicola*, and *L. neopolitana* to the synonymy of *L. dubia*. Accordingly, he gives a much more extended distribution for the latter as follows:

East coast of North America; North-East Atlantic from Brittany and the Channel Islands as far south as Senegal and Madeira and the Azores; Mediterranean: Gulf of Naples, Spezia, Messina, Marseilles, Syracuse, coast of Algeria; Adriatic: Gulf of Trieste; West Indies; Brazil; Indo-Pacific: Loyalty Islands, Isle of Pines, Ceylon and the Red Sea.

Additional recorded localities for *L. dubia* are: Black Sea (Băcescu, 1938), Hawaiian Islands (Miller, 1940), Japan (Shiino, 1951), British Columbia (Fee, 1926), Washington (Hatch, 1947).

Brown (1957), following Barnard (1925b), also considered several species of *Leptochelia* identical, namely, *L. savignyi*, *L. dubia*, *L. edwardsi*, and *L. lifuensis*. Priority is in the order named since the first three were described by Krøyer in 1842 on pages 168, 178, and 191, respectively, and the last was named by Stebbing in 1900. Thus, Barnard and Brown rightly deem *L. savignyi* to be the correct name and assign *L. dubia* and the others to its synonymy. As mentioned above, Larwood also regarded *L. dubia* and *L. savignyi* (among others) as conspecific but erroneously reversed the priority, relegating the latter to the synonymy of the former. In any event, all three authors indicate that the characters on which specific distinctions have been made, particularly the number of joints in the inner branch of the uropod, are too variable to have taxonomic significance.

The present author prefers to suspend judgment on the synonymy of several species of *Leptochelia*, particularly as to whether or not *L. dubia* and *L. savignyi* are conspecific, until more conclusive evidence is available. Certainly indicated is a critical comparison of the species in question based on adequate samples (including individuals of different size and sex) from representative localities. The fact that the forms named *L. dubia* generally have been reported from warmer waters than those named *L. savignyi* supports Monod's opinion that the former is a tropical-subtropical cosmopolite. Theoretically, such ecological segregation of these benthic forms with no apparent means of active dispersal could have resulted in their specific divergence.

Family Tanaidae

Anatanais normani (Richardson) Nordenstam

Figure 4

Localities.—California: Catalina Island (Stations 64, 66); Anacapa Island (Station 67); Santa Barbara Harbor (Station 68).

Remarks.—Richardson (1905a, 1905b) described this species (as *Tanais normani*) from specimens collected at Monterey Bay, central California. It has been reported subsequently from British Columbia (Fee, 1926; Hatch, 1947). The author has collected it intertidally at Moss Beach, San Mateo County, central California. The present report extends its range considerably southward into southern California.

Tanais species

Figure 4

Locality.—Central California: San Pablo Bay (Station 87).

Remarks.—The single tanaid taken in the north end of greater San Francisco Bay was mutilated too badly for specific identification. Antennae and gnathopods were missing and the head was damaged. The three pairs of pleopods and single branched uropod on a 5-segmented pleon are enough to determine that it belongs to the genus *Tanais*. Unfortunately, there is no tanaidacean material from San Francisco Bay or even published records of species in this area available for comparison.

Discussion

Incidence.—In general, Isopoda and Tanaidacea are represented poorly in the buoy collection both in numbers of species and in frequency of occurrence. The 29 species collected represent a small fraction of the isopods and tanaidaceans known to occur in the regions surveyed. On the west coast, for example, Menzies and Barnard (1959) list 36 benthic species of Isopoda in southern California, but only five were found on buoys in that region. Again, in the intertidal zone of central California, Menzies and Miller (1957) list 56 isopod species belonging to the four suborders represented in the buoy collection, but only eight species were taken from buoys in that region. As for tanaidaceans, only one species of the six listed for central California was collected from buoys. Finally, in the northwest Pacific, Hatch (1947) lists 45 flabelliferan, valviferan, and asellote isopods (no anthurideans), and seven tanaidacean species; but only two isopod species and no tanaidaceans were taken from buoys in that region.

As previously noted, isopods were collected from only about 25 percent of the buoys sampled and tanaidaceans were found on less than four percent of them. By contrast, amphipods (notably caprellids) were found on 98.9 percent of the buoys sampled—about the same incidence as barnacles (Cirripedia). Other crustaceans, such as decapods and copepods occurred in a relatively small fraction of the samples—about the same as isopods. Reasons for these differences will be considered later.

Another feature of the collection is the unequal representation of the seven isopod families (table 2). Between them, the Sphaeromatidae, Idoteidae, and Janiridae contributed 22 of the 26 isopod species and 111 of the total of 115 occurrences by species, not to mention the predominance of individuals belonging to these three families.

Several reasons or combinations of reasons may be advanced to account for the paucity of isopods and tanaidaceans in the collection, their low incidence on buoys, and the differences in frequency of occurrence of various crustacean groups: (1) inadequate sampling, (2) limited harborage presented by buoys, (3) difficulty of access, and (4) varying degrees of motility in different groups.

The necessarily opportunistic sampling program and wholesale collecting methods are partly responsible for the deficiency of isopods and tanaidaceans. In some areas too few buoys could be sampled, and those sampled could not be selected for diversity of local ecological conditions. The number of species and individuals occurring on buoys would depend a great deal on the composition of attached fouling organisms that might serve for food, cover, or a temporary substrate for transient crustaceans. Some doubtless occur by chance encounter, but others may be attracted to the buoy and be induced to remain there by the type of fouling and associated organisms present; for instance, swarms of *Synidotea laticauda* on several buoys in San Francisco Bay doubtless were feeding on colonial hydroids. Species of *Idotea* often were associated with kelp attached to buoys in temperate waters. Sphaeromatids tend to occur on buoys with "soft fouling" (tunicates, bryozoans, hydroids, etc.) in bays and harbors.

Greater variety and numbers also might have been obtained if the time and season of collecting could have been chosen. Buoys sampled a short time after cleaning or replacement, as some were, would not be expected to yield as many kinds and specimens as they might later when more heavily fouled. The season of sampling might also introduce sampling errors since the composition of fouling and associated organisms may vary through the year as a result of seasonal or occasional variations in ambient water temperature, salinity, currents, turbidity, and other factors; hence, periodic sampling of buoys doubtless would give better results than single visits.

The somewhat crude sampling techniques employed also contributed to the paucity of free-living crustaceans and other such creatures in the buoy collections. A major difficulty was that there was no way of preventing unattached forms from deserting the buoy installation while it was being hoisted aboard. Also, it was not possible to screen the samples by using wash bucket and plankton net procedures for extracting small free-living crustaceans from the scrapings. Consequently, many specimens could be lost or destroyed easily, especially if they were small or not abundant.

Besides sampling problems, other inherent difficulties reduced the yield. In the first place, buoy installations obviously comprise an extremely small and rather special vertical extension of the benthic habitat. Buoys are not sited in all habitat types in an area, nor do they necessarily acquire the full complement of species present in their vicinity. Space on buoys is limited, especially on the chain, and access may be difficult, especially for predominantly benthic species. Also, in many instances, chafing or scouring of the lower part of the chain may remove or prevent attachment of fouling and associated organisms. The fact that only a single isopod or tanaidacean species was found on 78 of the 100 buoys from which these crustaceans were taken indicates that buoys present rather limited, unnatural habitats not particularly attractive to these forms.

A possible explanation for the marked differences in incidence of various crustacean groups is the apparent correlation of frequency of occurrence with degree of motility and means of dispersal. Obviously, pelagic forms would stand a better chance of finding and boarding a buoy installation than would benthic types. The high incidence of barnacles and other sessile organisms on buoys can be explained readily by the fact that the sessile adults liberate swarms of pelagic larvae that find buoys to be a convenient substrate for attachment. Peracarid crustaceans, however, including amphipods, isopods, and tanaidaceans, generally lack pelagic larval stages, as the females carry the young in a subthoracic brood pouch until they are relatively well advanced. Liberated young usually resemble adults in habit and appearance, except for size and minor morphological differences, such as undeveloped seventh legs.

The high incidence of amphipods (99 percent) and the lesser frequency of isopods (*c.* 25 percent) the tanaidaceans (less than 4 percent) probably reflects the relative locomotor abilities of these three orders. The greater swimming ability of most amphipods could account for the fact that they are recorded in greater frequency and with greater variety than isopods not only from buoys but from other floating or suspended structures such as ships and test panels (Woods Hole Oceanographic Institution, 1952).

The foregoing comparison is rather crude, as no distinction was made between benthic and pelagic groups of amphipods and isopods. Natatory isopods, notably sphaeromatids and idoteids are represented much better in the buoy collection than predominantly crawling forms such as anthurids and tanaidaceans. Further, it is significant that bottom-dwelling isopods and tanaidaceans were taken generally from the anchor or from lower on the chain than more pelagic species, which were found higher on the chain and on the buoy itself, often at or near the waterline (table 2). More than half of the occurrences of sphaeromatids and idoteids were within the first meter below the waterline, and about three-fourths of them were within the first five meters below the surface. On the other hand, no anthurid was found less than 10 meters from the surface, and more than half of the occurrences of tanaidaceans were below five meters, with only 17 percent within the first meter from the surface. The fairly high incidence of janirid isopods, which are not noted for their swimming ability, may be associated with the fact that they often cling to floating seaweed, as do many of the better swimmers. Currents doubtless transport swimming or floating crustaceans considerable distances and may waft them against buoys.

If locomotor ability were solely responsible for differences between groups in incidence and distribution in buoys, one should expect that benthic caprellids and corophiids would be less abundant than natatory amphipods. Unfortunately, the amphipods of the buoy collections have not been worked up sufficiently for such comparisons. The impression gained from collecting and sorting, however, is that caprellids are as well represented on buoys as natatory gammarideans—if not more so.

Dispersal.—As was expected, most of the isopods and tanaidaceans taken from buoys belong to indigenous or to cosmopolitan species known to occur in the region. There were, of course, many new locality records within previously established limits. In some instances, however, known geographic ranges were extended, especially in regions that have not been surveyed adequately for these crustaceans. Many extensions were for relatively short distances and of no great biological significance. Some species, however, were found at stations far from any previously recorded locality. Extralimital species are of special interest in relation to means of dispersal and establishment of introduced species in new regions. Several noteworthy examples are discussed below, including *Sphaeroma walkeri* and *S. terebrans*, *Idotea balthica* and *I. metallica*, and *Carpias bermudensis*.

The discovery of *Sphaeroma walkeri* in several widely separated localities in Florida and in the Hawaiian Islands was surprising as this species has never before been reported from the central Pacific

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or North America. It was known previously from the coastal regions of India, the Red Sea and Suez Canal, South Africa, South America, and Australia. Now it appears to be a circumglobal, essentially warm water species, but with spotty distribution. Several large gaps remain, however, notably the eastern Pacific and eastern Atlantic. The disjunct distribution of *S. walkeri* might be explained on the basis that the present populations are relicts of a once continuously distributed, circumtropical cosmopolite; however, the alternative explanation that follows seems more plausible.

As previously mentioned, shipping probably has been responsible both for the wide dispersal and for the discontinuous distribution of *Sphaeroma walkeri.* The fact that this wood-boring species has been taken from wooden hulls and that it has a spotty pattern of distribution support this view. It is likely that transport by driftwood or by natural rafts carried by currents has been involved to some extent in the distribution of this species, but it seems unlikely that the vast distances and other barriers between some of its recorded localities could have been traversed by such passive carriers.

Another wood-boring isopod in the buoy collection, *Sphaeroma terebrans,* also has been found on ship bottoms as well as in dead wood. These agencies doubtless have been responsible for the worldwide distribution of this species. A documented case of dispersal of an isopod by ships is given by Chilton (1911). He recovered live females and males of a sphaeromatid (*Cymodoce tuberculata*) from the hull planking of the British Antarctic research vessel *Terra Nova* in dry dock in Lyttelton, New Zealand, after her arrival from Port Phillip, Australia. Since the species was unknown from New Zealand but common in Australia, Chilton concluded that these isopods were transported some 1200 miles between the two ports.

Floating seaweed carried by currents probably has contributed to the wide distribution of two idoteids that are well represented on New England buoys, namely *Idotea balthica* and *I. metallica.* Both species have marked swimming ability and the habit of clinging to floating seaweed.

The new locality records for *Carpias bermudensis* provide a basis for the following hypothesis regarding the origin and dispersal of this species: Hitherto known only from Bermuda, it was found on several buoys on the east coast and Key West regions of Florida. It is now suspected that this species originated and is well established in the Antillean region and that it has been transported northward to Bermuda by the Gulf Stream, possibly clinging to floating seaweed. The well-known affinity of the Caribbean and Bermudan marine faunas support this interpretation. The converse possibility—origin in

Bermuda and transport to the Antillean region, probably by boats—seems less plausible. A crucial point, which can be determined only by more collections, is how well and widely is it established in other parts of the Antillean region.

ESTABLISHMENT OF INTRODUCED SPECIES.—The above-cited examples leave little doubt that isopods and related crustaceans can and have been dispersed considerable distances by various means and that the transported species have become established in new localities. As Hedgpeth (1957) states, establishment requires some minimum population, as well as ecologically favorable conditions.

Enough immigrants of both sexes or a sufficient number of females carrying young in the brood pouch must be introduced to sustain a colony. How many individuals would be required is problematical, but probably more than a single pair or a single ovigerous female would be needed. Predators such as fish easily might wipe out the immigrants or reduce their numbers below the minimum sustaining level. The aliens might not be able to compete with or outbreed native species occupying the same ecological niche. On the other hand, absence of predators or a selective advantage of some sort over competitors would favor establishment of the introduced species. In any event, chance would play an important role in establishment.

One established, introduced species may radiate into different, perhaps unoccupied, ecological niches in the new region. Segregated, populations may undergo speciation as a consequence of reproductive isolation, mutation, genetic drift, and natural selection. Many of the taxonomic difficulties encountered in zoogeographical studies may be attributed to differentiation of local, isolated races, perhaps incipient species.

Ecological conditions in the new environment must be favorable not only for survival but also for reproduction of the introduced species. As Hutchins (1947) points out, within the survival limits for any ecological factor, there is a somewhat narrower range of conditions over which reproduction and repopulation can be completed. For temperature, he shows that maximal and minimal values for survival and/or reproduction are the critical parameters limiting the north-south distribution of many species. That temperature is an important limiting factor for isopods is evident from the latitudinal zonation shown by many species and even higher taxa.

Likewise, extremes (more so than averages) of other factors such as salinity may be limiting. Whether or not these conditions operate directly on the survival and reproduction of the animals themselves, or indirectly through their influence on other organisms on which they depend, or through a combination of both, is difficult to say without experimental evidence.

Geographical distribution.—On the basis of their recorded distributions (including the localities herein reported), the species represented in the buoy collection may be grouped geographically as follows.

Five isopod and one tanaidacean species (about 20 percent of the total) are widely distributed, occurring at least in both the Atlantic and Pacific oceans: *Cirolana parva*, *Idotea balthica*, *I. metallica*, *Leptochelia dubia*, *Sphaeroma terebrans*, and *S. walkeri*. It should be noted, however, that the distribution of this group in the Pacific is rather skewed. Only one of these (*Leptochelia dubia*) has been reported from the eastern Pacific, three of them (*L. dubia*, *Cirolana parva*, and *Sphaeroma walkeri*) are now known from the central Pacific, but all six occur in the Indo-Pacific region. Interestingly, *Leptochelia dubia* is the only species in the collection known to occur on both the Atlantic and Pacific coasts of the United States, as well as in the Bahamas and Hawaiian Islands. Two other cosmopolitan species taken in Hawaii, *Cirolana parva* and *Sphaeroma walkeri*, also occur off the Florida coast but not on the Pacific coast. Present knowledge of the isopod and tanaidacean faunas of the vast Pacific is much too incomplete as yet for safe generalization.

The remaining 80 percent (approximately) of the species are separated by the continental barrier—nine on the eastern side and 14 on the west coast (fig. 2; table 2). In at least one case, an eastern and western species comprise a "species pair," that is, morphologically closely related species occurring under similar ecological conditions on opposite sides of a major barrier. Fitting this definition are *Paracerceis caudata* found on buoys in warm waters of the Atlantic, Caribbean, and Gulf of Mexico, and its close morphological relative, *P. sculpta*, taken from buoys in tropical-subtropical waters in southern California and Hawaii (fig. 3). The Atlantic and Pacific coast species of *Idotea* also may be ecological equivalents in temperate waters.

On both sides of the continent, the species may be divided roughly into northern and southern groups, although a few species have extended north-south ranges along the coast. The locality data are too limited for precise definition of boundaries between northern and southern faunas and certainly for any subdivision of these groups. For sake of analysis, however, two well-known temperature and biotic break-points were selected—Cape Hatteras, at 35½°N latitude on the Atlantic coast and Point Conception at 34½°N latitude on the Pacific coast (Hutchins, 1947).

Although the two break-points are nearly at the same latitude, the temperature changes they signify and the temperature zones they divide on the opposite coasts are not exactly comparable. According to Dana's (1852) isocrymal chart, Cape Hatteras lies at the point at which the isocryme of 62°F leaves the Atlantic coast, whereas Point Conception is about the intercept of the isocryme of 56°F on the Pacific coast. Cape Hatteras thus divides the warm Temperate Zone waters that extend southward along the Atlantic coast to Cape Kennedy (Canaveral), Fla., from the colder temperate waters that range northward from it. On the Pacific coast, however, Point Conception separates the Temperate Zone waters of southern California and northern Baja California from the Subtemperate Zone waters of the central California coast. Moreover, the warmer coastal waters of Florida, the Bahamas, and Gulf coast lie in the Subtorrid Zone (bounded by the isocrymes of 68°F and 74°F), but this zone is not represented along the Pacific coast of the United States. Although the west coast waters south of Point Conception are colder than those of corresponding latitudes along the Atlantic coast, the coastal waters of the northwest Pacific coast are warmer than those of the New England coast. The Subfrigid Zone (bounded by isocrymes of 35°F and 44°F) extends as far south as Cape Cod on the Atlantic coast but only to the Straits of Juan de Fuca on the Pacific coast.

The northern Atlantic group comprises *Janira alta* and *Idotea phosphorea* plus the widely distributed *I. balthica* and *I. metallica*. All these were collected from buoys north of Cape Hatteras and are not known to occur south of it.

The southern Atlantic coast species merge with those of the Caribbean and Gulf of Mexico and include: *Accalathura* species,* *Carpias bermudensis*, *Cymodocella* species,* *Exocorallana subtilis*, *Paracerceis caudata* and *Skuphonura* species,* plus the widely distributed *Cirolana parva*, *Sphaeroma walkeri*, and *Leptochelia dubia*. Three of these (asterisks) were found only in the Bahamas.

Another Atlantic coast species, *Sphaeroma quadridentatum*, cannot be assigned to either northern or southern group as its range extends from southern New England to Key West, Fla. In the present study it was collected both north of Cape Hatteras in the mouth of Chesapeake Bay and well south of it in Florida. As most of its recorded localities are south of Cape Hatteras, this species is associated more closely with the southern group.

The northern Pacific group comprises *Dynamenella benedicti*, *Gnorimosphaeroma oregonensis*, *Ianiropsis kincaidi derjugini*, *Idotea wosnesenskii*, *Idotea stenops*, *Synidotea laticauda*, *Synidotea* species, and *Tanais* species. None of these occurs south of Point Conception. Two are quite common along the entire Pacific coast north of Point Conception—*Gnorimosphaeroma oregonensis* and *Idotea wosnesenskii*. By contrast, *Synidotea laticauda* is restricted to San Francisco Bay. There it has become adapted apparently to the lower salinities, higher temperatures, greater turbidity, currents, and wider fluctuations in environmental factors prevailing in the bay as compared to the open seacoast.

The southern Pacific group is poorly defined in this survey. Although six species were taken only from buoys along the southern California coast, only one has never been reported north of Point Conception, namely, *Paracerceis sculpta.* Of the remaining five species, three are known from both southern and central California (*Jaeropsis dubia, J. d. paucispinis,* and *Janiralata rajata*); one has been found in southern and central California and British Columbia (*Anatanais normani*); and one is known to be distributed along the entire Pacific coast from southern California to Alaska (*Idotea resecata*). The latter two species actually should not be assigned either to the southern or to the northern Pacific group. It should again be emphasized that the buoy collections do not sample adequately the long Pacific coast or even the included section between San Diego and Puget Sound and that knowledge of the systematics and distribution of isopods and tanaidaceans of the Pacific is incomplete.

As indicated above, the latitudinal zonation on both coasts is definite for two isopod families, the Idoteidae and Sphaeromatidae. All eight idoteids in the collection were found on northern buoys, generally associated with kelp, whereas all but one of the eight sphaeromatids were taken from warm water buoys, usually associated with muddy or sandy bottoms often with soft fouling (tunicates, etc.). Several exceptions may be noted in both families. As previously mentioned, *idotea resecata* ranges from Los Coronados Islands (off San Diego, Calif.) to Alaska, and in the present survey it was collected on buoys as far south as Santa Barbara. Two other idoteids (*Synidotea harfordi* and *S. magnifica*) are known only from southern California (they were not taken in the buoy survey). Conversely, two sphaeromatids in the buoy collection from cold waters are *Gnorimosphaeroma oregonensis*, a common species along the entire Pacific coast north of Point Conception but absent in southern California, and *Sphaeroma quadridentatum,* which ranges both north and south of Cape Hatteras on the Atlantic coast. Many other sphaeromatids (not taken in the collection) also occur in northern waters; nevertheless, as a rule, idoteids (and other valviferans) generally are found in cold waters and sphaeromatids in warm waters.

Not only are idoteids poorly represented in tropical-subtropical regions, but also those found there are relatively small (e.g., *Colidotea edmondsoni* of Hawaii) compared to more northern species. Indeed, valviferans seem to follow Bergmann's rule (for homoiotherms) as they tend to increase in size poleward with some frigid zone species being remarkably large (e.g., *Glyptonotus* species in the Antarctic and *Saduria* species in the Arctic region). The paucity of valviferans in the tropics, however, runs contrary to the abundance of warm water species in other isopod suborders and in invertebrates generally.

Only three isopod species and no tanaidaceans were found on Hawaiian buoys, a scanty representation of the fauna there. Two are cosmopolitan, *Cirolana parva* and *Sphaeroma walkeri;* the other, *Paracerceis sculpta,* probably was introduced into Hawaiian waters by naval shipping from southern California.

The Bahaman fauna was represented only slightly better with four isopod and one tanaidacean species. The tanaidacean was the cosmopolitan *Leptochelia dubia.* Of the isopods, *Paracerceis caudata* is a common sphaeromatid along the Atlantic and Gulf coasts and in Bermuda. The remaining three—*Cymodocella* species, *Accalathura* species, and *Skuphonura* species—were found only in the Bahamas but doubtless have wider distribution in the Antillean region.

Regarding generic distribution, half of the 16 isopod genera represented in the present study are known to occur along both the Atlantic and Pacific coasts of North America. They are *Cirolana, Dynamenella, Excorallana, Idotea, Janira?, Paracerceis, Sphaeroma,* and *Synidotea?.* Actually, however, species of only two genera, *Idotea* and *Paracercies,* were collected from buoys on both coasts. All three tanaidacean genera represented in the collection have species on both coasts, but *Leptochelia* was taken only on Atlantic coast buoys and *Anatanais* and *Tanais* only on Pacific coast buoys.

The above listing of *Janira* and *Synidotea* as genera common to both coasts is questionable for the following reasons. According to Wolff's (1962) tabulations, only one species of *Janira* occurs on the Pacific coast. He gives Vancouver Island and western Canada among the localities for *Janira maculosa* (along with Greenland, Morocco, and Corsica), apparently on the basis of Fee's (1926) and Hatch's (1947) reports. Menzies (1951, p. 123) states, however, that he personally has examined the specimens reported by Hatch and is of the opinion that they belong in the genus *Ianiropsis* G. O. Sars. He thinks the same is probably true of the specimens reported by Fee. All other Pacific coast forms previously assigned to *Janira* by earlier authors have been transferred to *Janiralata* Menzies, *Ianiropsis* G. O. Sars, or *Bagatus* Nobili (Menzies, 1951; Kussakin, 1962; Wolff, 1962); hence, the occurrence of *Janira* in the Pacific, at least the eastern part, is doubtful. The listing of the predominantly North Pacific genus *Synidotea* as occurring both on the Atlantic and Pacific coasts is also tenuous, but two circumboreal species (*S. bicuspida* and *S. nodulosa*) have been reported in the far North Atlantic near Greenland, Labrador, and Halifax. These are the only reports of *Synidotea* in the North

Atlantic. It might be mentioned, however, that species of this genus occur on the South Atlantic coasts of South America (*S. marplatensis* and *S. sphaeromiformis*) and Africa (*S. hirtipes*).

The remaining eight isopod genera are divided evenly between the two coasts. The east coast genera are: *Accalathura*, *Carpias*, *Cymodocella*, and *Skuphonura*. The following four genera are represented on the Pacific coast but not on the Atlantic: *Gnorimosphaeroma*, *Ianiropsis*, *Jaeropsis*, and *Janiralata*. Although absent from the Atlantic coast, *Ianiropsis* and *Jaeropsis* are represented elsewhere in the North Atlantic (Wolff, 1962). *Ianiropsis breviremis* occurs in the northeastern Atlantic (British Isles, Denmark, western Norway). As for *Jaeropsis*, one species (*J. brevicornis brevicornis*) occurs on the northwest coast of France and on the Channel Islands, and another (*J. rathbunae*) is found in Bermuda.

Six of the seven isopod families and both tanaidacean families represented in the buoy collections occur on both the Atlantic and Pacific coasts. The one exception, the monogeneric family Jaeropsidae, is absent from the Atlantic coast, but, as previously mentioned, it is represented by a species in Bermuda and by another on the Atlantic coast of Europe; hence, the continent is no barrier to distribution, at least of the isopod and tanaidacean families in the present study. As indicated above, the continental barrier is progressively more effective for lower taxonomic categories—about 50 percent at the generic level and about 80 percent at the specific level.

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TABLE 1.—*Buoy stations with Isopoda and/or Tanaidacea*

Station	Water depth (m)	Bottom	Exposure time (months)	Species	Number of specimens	Depth found (m)
NORTH ATLANTIC COAST: Gulf of Maine						
1. Explosive Anchorage-Nantucket Roads "B"	11.1	-	12	*Idotea phosphorea*	2	11.1
2. North Cut Buoy #3	5.5	-	31	*Idotea phosphorea*	2	0.6
3. Black Cove Buoy #2	9.2	mud	26	*Idotea phosphorea*	1	0.9
4. Fort Preble Channel Buoy #2	4	-	13	*Idotea balthica*	1	0
5. Fort Preble Channel Buoy #1	4	-	13	*Idotea balthica*	1	0
				Idotea phosphorea	2	0
6. Northwest Ledge Buoy #3	5.5	-	13	*Idotea phosphorea*	7	0, 5.5
7. Cashe Ledge Whistle Buoy CW	49.8	hard	12	*Janira alta*	1	40
8. Jeffrey Ledge Whistle Buoy #2 JL	55.4	hard	12	*Janira alta*	1	55.4
9. Boon Island Lighted Whistle Buoy #22 A	28.3	hard	12	*Janira alta*	1	-
Nantucket Sound and vicinity						
10. Quick's Hole Bell #1	21.5	black mud	31	*Idotea balthica*	1	0.6
11. Can #3—No Man's Land—Old Man #1	12.3	black mud	32	*Idotea phosphorea*	1	1.8
12. Nantucket Bar Bell Buoy	8.6	sand	5	*Idotea phosphorea*	1	1.8
13. Naushon Lighted Bell Buoy	18.5	mud	25	*Idotea phosphorea*	1	-
14. Horseshoe Shoal Lighted Buoy #12 A	16	hard	7	*Idotea phosphorea*	4	16
15. New Bedford Channel Lighted Buoy #2	8	sandy mud	13	*Idotea balthica*	1	0.3
16. Station Buoy for Half Moon Shoal LB Buoy #12	13.8	sand	12	*Idotea phosphorea*	5	3.7, 9.2, 13.8
17. Hedge Fence LT and GB #16	16.6	mud?	8	*Idotea phosphorea*	1	2.8
18. Squibucket Shoal Lighted Bell Buoy #1	20.3	hard sand	8	*Idotea balthica*	1	0.9
				Idotea phosphorea	5	0.9, 1.8, 2.8
19. Fifteen Foot Shoal Buoy #9	10.8	sandy	26	*Idotea phosphorea*	1	0.9
20. Great Rip Lighted Buoy #2	29.5	-	12	*Idotea phosphorea*	4	1.8
21. Davis South Shoal Fishing Buoy #2	11.1	-	12	*Idotea phosphorea*	2	1.8
22. Point Rip Lighted Bell Buoy #11 A	15.4	hard?	10	*Idotea phosphorea*	1	1.8
23. Great Round Shoal Buoy #8	11.1	hard?	10	*Idotea phosphorea*	35+	1.5
24. McBlair Shoal Buoy #7	15.4	-	12	*Idotea phosphorea*	18	18.5
25. Great Round Shoal Buoy #4	23.3	-	8	*Idotea phosphorea*	1	23.3
26. Newport AS Net	15.4	hard	30	*Idotea phosphorea*	7	-
New York region						

TABLE 1.—*Buoy stations with Isopoda and/or Tanaidacea*—Continued

Station	Water depth (m)	Bottom	Exposure time (months)	Species	Number of specimens	Depth found (m)
27. Craven Shoal Lighted Bell Buoy #19 A	11.1	mud	5	*Idotea phosphorea*	1	2.8
28. Fairway Lighted Whistle Buoy A	76	mud	14	*Idotea metallica*	1	0
29. Block Island Fairway Lighted Whistle Buoy C	61	mud	13	*Idotea metallica*	2	0
30. Fairway Lighted Bell Buoy D	59	mud	13	*Idotea metallica*	3	0
31. Fairway Lighted Whistle Buoy E	61	sandy mud	13	*Idotea metallica*	1	0
MID-ATLANTIC COAST: Norfolk, Va.						
32. Hampton Roads Obstruction LB B	20	hard mud	13	*Sphaeroma quadridentatum*	6	0
33. Hampton Roads Obstruction LB A	26	mud-clay	5	*Sphaeroma quadridentatum*	7	0
Cape Lookout, N.C.						
34. New River Whistle Buoy N	14.7	sand-shell	15	*Paracerceis caudata*	7	0.9
35. Cape Lookout Shoal Obstruction Lighted Buoy W	16.6	–	12	*Paracerceis caudata*	2	0.9
FLORIDA COAST: East Coast						
36. Ponce de Leon Inlet Lighted Whistle Buoy #2	14.1	black mud	7	*Sphaeroma walkeri*	62	0.9, 1.5, 1.8, 3.7
37. Bethel Shoal Station Buoy	14.8	hard	10	*Carpias bermudensis*	3	14.8
38. Port Everglades Entrance Buoy #1 A	12.3	sandy?	18	*Paracerceis caudata*	1	12.3
South Coast (Florida Keys)						
39. Satan Shoal Buoy	4.9	–	8	*Paracerceis caudata*	1	4.9
40. Twenty-four Foot Shoal	–	–	19	*Paracerceis caudata*	1	0
41. Key West north of Station 39	11.7	–	–	*Paracerceis caudata*	12	11.7
42. #1 Entrance Lighted Bell Buoy	27.6	white clay	5	*Sphaeroma terebrans*	1	0
43. Middle Ground South End Buoy #11	7.0	–	15	*Leptochelia dubia*	1	1.8
44. Anchorage Lighted Buoy #B 5	13	–	11	*Paracerceis caudata*	1	13
45. Anchorage Lighted Buoy C	13.8	–	11	*Carpias bermudensis*	9	1.5
46. Anchorage Lighted Buoy BB	15.4	gray clay-sand	11	*Leptochelia dubia*	3	15.4

TABLE 1.—*Buoy stations with Isopoda and/or Tanaidacea*—Continued

Station	Water depth (m)	Bottom	Exposure time (months)	Species	Number of specimens	Depth found (m)
47. Northwest Channel Entrance Lighted Bell Buoy #1	8.3	gray clay-sand	7	*Leptochelia dubia*	7	0, 3.7, 8.3
				Paracerceis caudata	1	8.3
48. Obstruction Lighted Whistle Buoy #6	11.1	gray sand	15	*Paracerceis caudata*	92	1.1, 3.8, 11.1 5.5,
				Leptochelia dubia	30	11.1
				Carpias bermudensis	1	2.2
				Skuphonura species	1	11.1
West Coast						
49. New Pass Sarasota Lighted Buoy #1	6.5	-	10	*Sphaeroma walkeri*	2	0, 0.9
				Paracerceis caudata	1	0.6
50. Tampa Bay Lighted Whistle Buoy PS	14.1	sand-mud	13	*Paracerceis caudata*	3	14.1
				Excorallana subtilis	1	14.1
51. Egmont Channel Lighted Bell Buoy #2	10.4	black mud	17	*Sphaeroma walkeri*	2	0, 0.9
52. Channel Lighted Bell Buoy #4 K	6.5	black mud	10	*Sphaeroma quadridentatum*	1	3.7
TEXAS COAST						
53. Freeport Entrance Buoy #2	8.3	blue mud	16	*Sphaeroma terebrans*	2	0.9
54. Sabine Pass Channel Lighted Bell #2 A	9.2	gray mud	14	*Sphaeroma terebrans*	38	0, 8.6
55. Sabine Entrance Lighted Whistle #1	10.1	gray mud	14	*Sphaeroma terebrans*	33	0
56. Sabine Pass East Jetty Bell Buoy #2 B	9.2	gray clay	15	*Sphaeroma terebrans*	51	0, 0.9
57. Sabine Pass Channel Lighted Buoy #3	4.3	gray clay	20	*Sphaeroma terebrans*	200	0
58. Sabine Pass Channel Lighted Buoy #9	9.2	gray mud	5	*Sphaeroma terebrans*	3	-
				Leptochelia dubia	2	-
BAHAMAS						
59. Walker Cay	15.4	-	13	*Leptochelia dubia*	5	15.4
				Accalathura species	1	15.4
60. Walker Cay Lighted Buoy L	14.7	sand	13	*Leptochelia dubia*	1	14.7
61. Walker Cay #3	7.4	sandy	13	*Cymodocella* species	1	7.4
62. Walker Cay #5	5.8	sandy		*Paracerceis caudata*	1	5.8
				Leptochelia dubia	2	5.8
63. Walker Cay #4	7.4	-	13	*Leptochelia dubia*	1	7.4

TABLE 1.—*Buoy stations with Isopoda and/or Tanaidacea*—Continued

Station	Water depth (m)	Bottom	Exposure time (months)	Species	Number of specimens	Depth found (m)
CALIFORNIA COAST: Southern California						
64. Catalina Island, Isthmus Cove, Northwest Entrance Buoy #2	-	rocky	10	*Anatanais normani*	22	5.5, 9.2
				Jaeropsis dubia	8	9.2
				Janiralata rajata	20	9.2
65. Catalina Island, Isthmus Cove, Northwest Entrance Buoy #2	33.2	rocky	10	*Jaeropsis dubia*	1	-
66. Catalina Island, Isthmus Cove, North Entrance Buoy #1	-	rocky	10	*Anatanais normani*	44	1.8, 5.5
				Jaeropsis dubia	1	1.8
				Janiralata rajata	12	1.8
67. Anacapa Island	16.9	rocky	12	*Idotea (Pentidotea) resecata*	35	0.9
				Janiralata rajata	5	0.9, 11.1
				Anatanais normani	2	0.9
68. Santa Barbara Harbor #4	-	sand-mud	-	*Anatanais normani*	3	1.8, 3.7
69. Santa Barbara Buoy, Station B	33.2	sand-mud	8	*Idotea (Pentidotea) resecata*	1	0
70. Point Dume #6	-	-	8	*Jaeropsis dubia*	1	13
71. Los Angeles Harbor Entrance (temporary) Buoy B	15.4	sand-shell	7	*Jaeropsis dubia paucispinis*	1	5.5
72. San Diego Harbor (inside)	-	-	-	*Paracerceis sculpta*	-	0
Central California						
73. San Simeon Bell Buoy	-	-	25	*Idotea (Pentidotea) resecata*	3	0, 3.7, 5.5
				Idotea (Pentidotea) stenops	1	0
74. Oakland Outer Harbor Lighted Bell Buoy #1 A	-	-	7	*Gnorimosphaeroma oregonensis*	3	0.9, 1.8, 3.7
75. Yerba Buena Island Lighted Bell Buoy #2	-	-	4	*Gnorimosphaeroma oregonensis*	3	0.9
				Idotea (Pentidotea) wosnesenskii		0
76. Point Edith Buoy	6–9	-	12	*Gnorimosphaeroma oregonensis*	-	0
				Synidotea laticauda	-	1.8, 3.7
77. Suisun Bay Lighted Buoy #4	-	-	17	*Gnorimosphaeroma oregonensis*	-	0.9
78. South San Francisco Lighted Buoy #2 SSF	-	-	8	*Gnorimosphaeroma oregonensis*	1	0.9
79. San Francisco Buoy #1	-	-	11	*Synidotea laticauda*		7.4
80. San Francisco Bay South Channel Lighted Buoy #1A	8.9	-	12	*Gnorimosphaeroma oregonensis*	2	0

TABLE 1.—*Buoy stations with Isopoda and/or Tanaidacea*—Continued

Station	Water depth (m)	Bottom	Exposure time (months)	Species	Number of specimens	Depth found (m)
81. Alcatraz Bell Buoy	-	-	11	*Ianiropsis kincaidi derjugini*		0, 0.9
				Idotea (Pentidotea) wosnesenskii		0, 0.9
82. Carquinez Strait Restricted Area Buoy #1C	-	-	6	*Synidotea laticauda*	2	0, 0.9
83. Crissy Field Seaplane Station Buoy CF	-	-	8	*Synidotea laticauda*	many	0
84. Obstruction Valve Bell Buoy B	-	-	7	*Gnorimosphaeroma oregonensis*	1	3.7
				Idotea (Pentidotea) wosnesenskii	1	0
				Dynamenella benedicti	1	0
85. Red Rock Bank South End Lighted Bell Buoy #1	-	-	7	*Gnorimosphaeroma oregonensis*	3	0, 0.9, 1.8
86. Point San Pedro Mid-Channel Buoy	-	-	3	*Gnorimosphaeroma oregonensis*	many	1.8
87. San Pablo Bay Lighted Buoy #10	9.2	mud	12	*Gnorimosphaeroma oregonensis*	56	0, 0.9, 7.4
				Tanais species	1	0
				Synidotea laticauda	225	0.9, 1.8, 5.5, 7.4
88. Bonita Channel Lighted Whistle Buoy #4	-	-	18	*Ianiropsis kincaidi derjugini*	3	0, 0.9, 1.8
				Idotea (Pentidotea) wosnesenskii	1	0
89. Golden Gate Park Bell Buoy #4	12.3	sandy	11	*Ianiropsis kincaidi derjugini*	12	0.9
				Idotea (Pentidotea) wosnesenskii	1	0.9
90. San Francisco Bar Channel Buoy	-	-	9	*Synidotea* species	1	14.8
91. San Francisco Bar Channel Lighted Bell Buoy #5	-	-	9	*Gnorimosphaeroma oregonensis*	many	0
92. Noyo River Entrance Bell Buoy	11.1	-	2	*Ianiropsis kincaidi derjugini*	1	0
WASHINGTON COAST						
93. Clallam Reef Bell Buoy #1	24	rocky	5	*Idotea (Pentidotea) wosnesenskii*	1	0
94. Double Bluff Lighted Trumpet Buoy #1	10.1	rocky	8	*Idotea (Pentidotea) wosnesenskii*	1	0
95. Umatilla Reef Lighted Buoy UR	46.2	rocky	13	*Gnorimosphaeroma oregonensis*	12	1.8
96. Quillayute River Jetty Buoy #2	6.8	sand-mud	14	*Idotea (Pentidotea) wosnesenskii*	2	0
				Gnorimosphaeroma oregonensis	174	0, 0.9, 1.8, 2.7

TABLE 1.—*Buoy stations with Isopoda and/or Tanaidacea*—Continued

Station	Water depth (m)	Bottom	Exposure time (months)	Species	Number of specimens	Depth found (m)
HAWAIIAN ISLANDS						
97. Hilo Harbor, Hawaii, Special Nun #8	11.1	mud	2	*Paracerceis sculpta*	30	1.8
				Sphaeroma walkeri	1	5.5
98. Pearl Harbor, Oahu, 2nd Class Nun #28	15.4	mud	1	*Paracerceis sculpta*	82	0.9, 5.5, 7.4
99. Pearl Harbor, Oahu, 2nd Class Nun	12.9	mud	1	*Paracerceis sculpta*	78	0, 0.9, 3.7, 8
100. Port Allen, Kauai, #7	9.2	mud	8	*Cirolana parva*	1	7.4

TABLE 2.—*Occurrence and depth distribution (in meters) of Isopoda and Tanaidacea on buoys* (regions: A=Atlantic coast, B=Bahamas, G=Gulf of Mexico, H=Hawaii, P=Pacific coast)

Species	Regions	Number	Bottom depth		Frequency and depth of occurrence					
		of buoys	Range	Mean	0–1	1–5	5–10	10–20	20–40	40–60
Sphaeromatidae										
Gnorimosphaeroma oregonensis	P	13	8–46	15.7	13	8	1			
Sphaeroma quadridentatum	A,G	3	6–26	17.5	2	1				
Sphaeroma terebrans	G	7	4–28	11.1	7		1			
Sphaeroma walkeri	A,G,H	4	6–14	10.5	5	3	1			
Cymodocella species	B	1	–	7.4			1			
Dynamenella benedicti	P	1	–	–	1					
Paracerceis caudata	A,B,G	12	5–17	10.8	4	3	3	5		
Paracerceis sculpta	P,H	4	11–15	13	4	2	3			
Idoteidae										
Idotea balthica	A	5	4–20	11.6	5					
Idotea metallica	A	4	59–76	64.3	4					
Idotea phosphorea	A	21	4–30	13.7	6	10	2	4	1	
Idotea resecata	P	3	17–33	25.1	3	1	1			
Idotea stenops	P	1	–	–	1					
Idotea wosnesenskii	P	8	7–24	13.3	9					
Synidotea laticauda	P	5	8–9	8.4	4	3	3			
Synidotea species	P	1	–	–				1		
Janiridae										
Carpias bermudensis	A,G	3	11–15	13.2		2		1		
Ianiropsis kincaidi derjugini	P	4	11–12	11.7	6	1				
Janira alta	A	3	28–55	44.5					1	1
Janiralata rajata	P	3	–	16.9	1	1	1	1		
Jaeropsidae										
Jaeropsis dubia	P	4	–	33.2		1	1	1		
Jaeropsis dubia paucispinis	P	1	–	15.4		1				
Cirolanidae										
Cirolana parva	H	1	–	9.2			1			
Excorallanidae										
Excorallana subtilis	G	1	–	14.1				1		
Anthuridae										
Accalathura species	B	1	–	15.4				1		
Skuphonura species	B	1	–	11.1				1		
Paratanaidae										
Leptochelia dubia	B,G	9	7–15	10.5	1	2	3	4		
Tanaidae										
Anatanais normani	P	4	–	16.9	1	3	3			
Tanais species	P	1	–	9.2	1					

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