# Small Freshwater Organisms on Eniwetok Atoll[1]

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Many biologists have been interested in problems associated with the colonization of oceanic islands. See for example: Darwin, 1854; Darlington, 1938; Gulick, 1932; Gibson-Hill, 1950; Guppy, 1917; Ridley, 1930; and Zimmerman, 1948. Because of the rarity of events of colonization of such islands and the difficulty of adequate observation of these events, the mode of transport of each species found must be deduced from what is known about the species. Determination of the biota of oceanic islands is the first step in this process.

Eniwetok Atoll is near the north end of the Marshall Islands in the central Pacific Ocean. It is a dry island in that rainwater does not remain in surface depressions for long, and the total annual precipitation is about 53 inches. A study was made during the summer of 1963 to determine the existence and characteristics of a microsopic freshwater biota which might live in small, sporadically existing temporary bodies of fresh water on a very isolated atoll which lacks fresh surface water. The expectations were that freshwater communities would be found and would consist of few species and that therefore dispersal mechanisms and community structure would be easily amenable to study.

Collections of fresh water were made on four different islets of Eniwetok. Sterile syringes and containers were used. The water collected was usually (when there was enough) divided into several bottles and some of these were enriched with different amounts of a sterile suspension of 2 g. Cerophyl/100 ml. of water. All samples were kept about 15 cm. from a 40 watt GE cool white fluorescent light. Some samples were examined the day of collection; all were studied within two days of collection and periodically thereafter.

Sample bodies of water varied from 8 ml. to about 100 ml. and were made up of rainwater held by leaves lying on coral rubble, in pelecypod shells, in broken coconuts, in tree holes, in a broken beer bottle, and in leaf axils of the screw pine, *Pandanus*. When sample volume and time permitted, calcium+magnesium concentrations were determined for some of the samples by titration with EDTA, and $Cl^-$ concentrations were determined for some samples by titration with $AgNO_3$ (Mohr method).

Organisms were identified, usually when alive, and usually with the aid of keys in Edmondson's "Fresh Water Biology" (1959). Keys and descriptions by T. L. and F. F. Jahn (1949), A. Kahl (1930–35), R. R. Kudo (1954), R. W. Pennak (1953), G. W. Prescott (1954), and G. M. Smith (1950) were also used. Organisms were keyed only as far as they seemed to fit well into the key and to agree with appropriate descriptions.

The number of different kinds of small freshwater organisms, in view of the great isolation of the atoll and the general lack of fresh water is astounding.

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Table I. Distribution of freshwater organisms in various containers on Eniwetok. The numbers below "*Pandanus*" give the height (in meters) above ground of the leaf axil from which the collection was made.

| Collection | E3 | E2 | E19 | E4 | E20 | E9 | E7 | E1 | E10 | E11 | E12 | E13 | E14 | E17 | E15 | E18 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Container | Shell | Shell | Coco-nut | Coco-nut | Tree hole | Tree hole | Bottle | Leaf | Leaf | Leaf | Leaf | Pand-anus 0.4 | Pand-anus 0.6 | Pand-anus 2.5 | Pand-anus 3.0 | Pand-anus 5.0 | | |
| Volume (ml) | 12 | 40 | 15 | 40 | 30 | 48 | 80 | 35 | 10 | 12 | 20 | 12 | 8 | 38 | 36 | 20 | | |
| Hardness Ca+Mg (ppm) | | | | 105 | 116 | 212 | 42.7 | | | 47 | | | 210 | | 39 | | | |
| $Cl^-$ (Mohr) (ppm) | | | | | 9.0 | 120 | 102 | | | | | | | | 52.7 | | | |
| Sun (Su) or Shade (Sh) | Sh | Su | Sh | Sh | Sh | Sh | Sh | Sh | Sh | Sh | Sh | Sh | — | — | — | — | Total | Sandon |
| Chlamydomonaceae | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Palmellococcus* | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | 1 | |
| Unicellular alga (green) | 1 | — | — | — | 1 | — | — | — | 1 | — | — | — | — | — | — | — | 3 | |
| *Astasia* | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Peranema* | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Petalomonas* | — | — | — | 1 | — | — | — | — | — | — | — | ? | — | — | — | — | 2 | 1 |
| *Coccochloris* (=*Synechococcus*) | — | — | — | 2? | — | 1 | — | ? | — | — | — | — | — | — | — | — | 4 | |
| *Anacystis* | — | ? | — | ? | — | — | — | — | — | — | — | — | — | — | — | — | 2 | |
| Unicellular alga (blue-green) | 1 | — | — | 1 | — | — | — | — | — | — | — | — | — | — | 1 | — | 3 | |
| *Oscillatoria* | 1 | — | — | 1 | — | 1 | 1 | 2 | — | — | — | — | — | — | — | — | 6 | |
| *Phormidium* | — | — | — | — | — | — | ? | ? | — | — | — | — | — | — | — | — | 1.5 | |
| *Lyngbya* | — | — | — | ? | — | — | — | | — | — | — | — | — | — | — | — | 1.5 | |
| *Nostoc* | — | — | — | ? | — | — | — | — | ? | — | — | — | — | 1 | ? | — | 3 | |
| *Anabaena* | — | — | — | | — | — | — | — | | — | — | ? | — | 1 | — | 1 | 3.5 | |
| *Cylindrospermum* | — | — | — | — | — | — | — | — | — | — | — | | — | — | — | — | .5 | |
| *Stigonema* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | 1 | 2 | |
| *Hapalosiphon* | — | — | — | 1 | — | — | — | 2? | — | — | — | — | — | — | — | — | 3 | |
| *Amphithrix* | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Calothrix* | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| Filamentous alge (blue-green) | — | — | 1 | — | 1 | — | — | — | — | — | — | — | — | 1 | — | — | 3 | |
| *Oicomonas* | ? | — | ? | 1 | — | — | — | — | — | — | ? | — | ? | — | ? | 1 | 7 | |
| *Spiromonas* | — | — | — | 1 | — | — | — | — | — | — | — | 1 | — | 1 | — | ? | 4 | |
| *Monas* | 1 | — | — | 1 | — | 1 | ? | 1 | — | — | 1 | 1 | — | 1 | 1 | 1 | 10 | |
| *Bodo* | 2 | — | — | 1 | 1 | — | — | 1 | 1 | 1 | — | 1 | 1 | — | — | — | 9 | 1 |

| | | | | | | | | | | | | | | | | | | |
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| *Cercobodo* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | ? | 1 | 1 |
| *Penardia* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 | |
| *Mayorella* | ? | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Astramoeba* | — | — | — | 1 | — | ? | — | — | — | — | — | — | — | — | — | — | 2 | |
| *Flabellula* | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Chaos* (=*Amoeba*) | — | — | — | 1 | — | 1 | — | — | ? | — | — | 1 | — | — | — | 1, ? | 6 | ? |
| Hartmannellidae or Vahlkampfiidae | — | — | 1 | 1 | — | — | 1 | 1 | — | 1 | — | 1 | 1 | — | 1 | — | 8 | 1 |
| *Arcella* | — | 1 | — | 1 | — | — | — | — | ? | — | — | — | — | — | — | — | 3 | |
| *Hyalosphenia* | — | — | — | — | — | ? | — | — | — | — | ? | — | — | — | — | — | 2 | |
| *Centropyxis* | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Diplophrys* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 | |
| *Actinophrys* | — | — | — | — | 1 | 1 | — | — | — | — | — | — | — | — | — | — | 2 | |
| *Spathidium* | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Spasmostoma* | — | — | — | ? | — | — | — | 1 | ? | — | — | — | — | — | — | — | 3 | |
| *Chaenea* | ? | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Dileptus* | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Chilodonella* | — | — | — | — | — | — | — | ? | 1 | 1 | — | — | — | — | — | — | 3 | |
| *Gastronauta* | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Trichopelma* | — | — | 1 | 1 | — | 1 | 1 | — | 1 | — | 1 | 1 | 1 | 1 | 1 | 1 | 11 | |
| *Drepanomonas* | — | — | — | — | — | 1 | 1 | 1 | — | — | — | — | — | 1 | 1 | — | 5 | |
| *Microthorax* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 | |
| *Trichopelmidae* | 1 | — | — | 1 | — | — | — | 1 | — | — | — | 1 | — | — | — | — | 4 | |
| *Colpoda cucullus* | — | — | — | 1 | — | ? | — | 1 | — | — | — | — | — | — | — | — | 3 | 1 |
| *C. maupasi* or *aspera* | — | — | — | 1 | — | — | — | 1 | — | — | 1 | 1 | — | — | — | — | 4 | 1 |
| *C. steini* | — | — | — | — | — | — | — | — | — | 1 | 1 | — | 1 | — | — | — | 3 | 1 |
| *C. sp.* | 1 | — | 1 | — | 1 | 1 | 1 | — | 1 | 1 | — | 1 | 1 | 1 | — | — | 10 | |
| *Bresslaua* | — | — | 1 | — | — | — | — | — | — | — | — | 1 | — | 1 | 1 | 1 | 5 | |
| *Tetrahymena* | — | — | ? | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Glaucoma* | — | — | — | — | — | — | ? | — | — | — | — | — | — | — | 1 | — | 2 | |
| *Cinetochilum* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 | |
| *Cyrtolophosis* | — | — | 1 | — | — | — | — | — | — | — | — | 1 | ? | 1 | 1 | 1 | 6 | |
| *Cyclidium* | 1 | 1 | 1 | 1 | 1 | — | — | 1 | — | — | — | — | — | 1 | 1 | — | 8 | 1 |
| Pleuronematidae | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | 1 | |
| Holotrich | — | — | 1 | — | — | 1 | 1 | — | — | — | — | — | — | — | 1 | — | 4 | |

| Collection | E3 | E2 | E19 | E4 | E20 | E9 | E7 | E1 | E10 | E11 | E12 | E13 | E14 | E17 | E15 | E18 | Total | Sandon |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Onychodromus* | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |
| *Steinia* | — | — | — | 1 | 1 | 1 | — | 1 | 1 | — | — | — | — | — | — | — | 5 | |
| *Tachysoma* | — | — | 1 | ? | — | — | — | — | — | — | — | — | — | — | — | — | 2 | |
| *Histrio* | — | — | — | ? | — | — | — | ? | ? | 1 | 1 | — | — | — | — | — | 5 | |
| Oxytrichidae | — | — | — | — | — | — | 2 | — | — | — | — | — | — | — | 1 | — | 3 | |
| *Euplotes* | 1 | — | 1 | — | 1 | 1 | — | 1 | 1 | — | — | — | — | — | — | — | 6 | |
| *Vorticella* | 1 | — | 1 | 1 | — | 1 | — | — | — | — | — | 1 | 1 | — | — | — | 6 | 1 |
| Unidentified ciliates | 1 | 1 | 1 | — | 2 | 2 | 4 | 1 | — | 3 | 2 | 2 | 2 | 1 | — | 1 | 23 | |
| Rhabdocoel | 1 | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | |
| *Habrotrocha* | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | 1 | |
| *Mniobia* | — | — | — | — | — | — | — | — | 1 | — | — | 1 | — | — | — | — | 2 | |
| *Macrotrachela* or *Rotaria* | — | — | 1 | — | — | — | 1** | — | — | — | — | — | 1 | 1 | 1 | — | 5 | |
| *Adineta* | 1 | 1 | ? | 1 | — | 1 | 1 | — | — | — | 1 | 1 | — | 1 | 1 | — | 10 | |
| Bdelloidea | — | — | — | — | 1 | — | — | 1 | 1 | 1 | — | 1 | — | 1 | — | — | 6 | |
| Nematode | 1 | — | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | — | — | 14 | |
| *Macrobiotus* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 | |
| Tardigrade | — | — | — | — | 1 | 1 | — | — | — | 1 | — | — | 1 | — | — | — | 4 | |
| Oligochaete | — | — | 1 | — | — | — | — | — | 1 | 1 | — | — | — | — | — | — | 3 | |
| Collembola | — | — | 1 | 1 | 1 | 1 | — | — | 1 | 1 | 2 | 2 | 1 | — | — | — | 11 | |
| Mite | — | — | 1 | — | — | — | 1 | — | 1 | — | — | — | 1 | 1 | 1 | 1 | 7 | |
| Total | 19 | 5 | 25 | 34 | 15 | 22 | 19 | 24 | 18 | 15 | 14 | 22 | 15 | 17 | 22 | 13 | | 10 |
| Number of cultures | 1 | 1 | 3 | 5 | 3 | 5 | 2 | 5 | 5 | 1 | 4 | 2 | 1 | 4 | 2 | 3 | | |

* P=Pandanus leaf (dead); P. A.=Leaf axil of living *Pandanus*, distance refers to height above ground.

** Probably *Macrotrachela* because what probably was spiny rotifer egg found in culture.

The ? in dicates uncertainty concerning accuracy of identification. When ? appears between the lines associated with two consecutive genera it means that the organism was one or the other but in a condition which precluded decision concerning which (in these instances each genus was given credit for 1/2 of an occurrence).

There were at least 81. Table I gives the organisms identified, their distribution between the samples, the volume of water occurring in each container, chemical concentrations for some of them, whether the water was normally exposed to direct sunlight or was in the shade, and for the *Pandanus* leaf axils, their height above the ground.

Sandon (1927), in his classic survey of the protozoa of the soil, obtained three samples from Ocean Island and three from Nauru. He found 32 different kinds of protozoa in cultures of Ocean Island soils and 15 in Nauru soil cultures. This compares with 49 (a conservative estimate) protozoa from 16 water samples on Eniwetok. Ocean Island receives 82 inches of rain per year and Nauru receives 81 inches, compared with Eniwetok's 53 inches (Wiens, 1962). One might expect a larger number of protozoa to live on the wetter islands, but the difference in environment sampled, even though protozoan populations of standing water and of soil have many species in common (Sandon, 1927; Gray, 1948), makes comparisons unreliable.

In a study of the colonization of sterile water in bottles of various distances from a pond in central Texas, Maguire (1963) found a total of 84 recognizable different kinds of small fresh water organisms. The taxonomic levels to which some of the groups were identified were different in this case than in the Eniwetok study, the aquatic organisms were transported to the bottles either from the soil or from a single stock pond, and the bottles were alike in size and chemical composition (in contrast to the heterogeneity of the natural containers on Eniwetok) so that considerable caution must be exercised in making comparisons. However, differences between the algae in the two samples are so great that they probably are meaningful. In Eniwetok three different Chlorophyta were found as compared with 19 in Texas and there were 14 Cyanophyta in Eniwetok and 7 in Texas. Texas' limestone-derived soils have moderate growths of blue-green algae upon their surfaces and the coral rubble under many of the water holding containers samples on Eniwetok was black with covering blue-green algae. Whether or not the difference in the frequency of Cyanophyta is related to a relationship between nitrogen-poor soil and the nitrogen fixing ability of some of the blue-green algae is unknown, but this is an interesting problem which deserves further investigation.

Many of the small aquatic organisms found in the small bodies of water on Eniwetok Atoll are able to live as part of the soil biota as well as in standing water. The absence of rotifers other than the Bdelloids listed in Table I, all genera of which are represented in soil biotas (Kuhnelt, 1961), reinforces the suspicion that most if not all of the organisms found living in standing water on Eniwetok are at least facultative soil dwellers.

Standing water is sufficiently rare and ephemeral that mosquitoes have not become established on Eniwetok, although they are common throughout the wetter, southern Marshall Islands (Bohart, 1957). Fosberg (1946) reported that shallow freshwater wells had been dug on most islets of Eniwetok Atoll. A cistern built by the Japanese on Eniwetok during the Second World War did contain water for a number of years (Hiatt, 1963), but it is not known if it still exists. Examination of the literature (Kudo, 1954; Smith 1950; Desikachary, 1959;

Finley, 1930; Bold, 1964) suggests that only about one half of the genera listed in Table I have both marine and freshwater species or have species which can survive transfer from fresh to sea water or vice-versa. This is evidence that a large number of the organisms found in fresh water on Eniwetok were transported to the atoll and not merely adaptable but normally marine species.

Transport of some small aquatic organisms to Eniwetok may have resulted from the activities of the Micronesians or the Japanese or Americans during and after the last war. Never-the-less it is instructive that a large and varied assemblage of organismus has been able to reach the islands and to survive in very small and temporary bodies of water between which they must frequently disperse if they are to survive.

More effective study of dispersal based on the kinds of organisms present on an isolated island might be carried out where transport of disseminules to the island by man may have been less important than on Eniwetok. The best, but least practical method would be to find a small isolated island very recently formed on a previously submerged atoll by unusual typhoon generated water currents and to observe the course of its colonization. Alternatively it would probably not be very expensive to sterilize (methyl bromide?) some small isolated island and then to study its recolonization. In either case care should be taken to prevent transport of organisms to the island by human agencies.

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