Preliminary data on microcrustacean communities from ground waters in the southern Everglades

Maria Cristina Bruno[1], William F. Loftus[2] and Sue A. Perry[1]
[1] South Florida Natural Resources Center, Everglades National Park, Homestead, Florida 33034 USA
[2] U.S. Geological Survey, Biological Resources Division, Everglades National Park, Homestead, Florida 33034 USA.

ABSTRACT

We studied ground-water crustacean communities by collecting samples from three sets of wells located in the Rocky Glades area of Everglades National Park (ENP), the Atlantic Coastal Ridge northeast of ENP, and along canals southeast of ENP. In each well, we sampled at different depths, monthly from June to December 2000. Copepods collected included both calanoid species, 22 of the 27 species of cyclopoids, and 2 of the 8 species of harpacticoids reported from Everglades National Park. We also collected several isopods, amphipods, and ostracods that were identified at the generic level. The numbers of copepod species and individuals varied with time, and with depth class, suggesting that surface water copepods use ground water as a refuge from predators, or as a feeding site during the wet season. Surface-dwelling taxa become more numerous when the ground-water level decreased, at the end of the wet season. We documented faunal exchange from surface to ground waters and vice versa, and for the wells along the Coastal Ridge canals, movements to and from the canals into ground water.

INTRODUCTION

The ground-water realm has been included in freshwater ecological studies only recently, and the knowledge of its function and structure are still very incomplete (Danielopol, 1989). Ground-water ecology is a field of study that has developed slowly in the past, mainly due to methodological difficulties related to the sampling and observation of the subsurface environment. Although ground water is known to be a complex living ecosystem, faunistic data have often been neglected. Many authors have demonstrated that surface and subterranean fauna colonize the different habitats of the highly structured, subsurface environment according to their ecological tolerance and preferences (Danielopol, 1991a; Rouch, 1991; Dole-Olivier and Marmonier, 1992). The faunal assemblages also reflect certain hydrological, geomorphological, physical and chemical processes (Amors and Mathiaeu, 1984; Creuzé de Chatellierers and Reygobellet, 1990; Lafont and Durbec 1990). Therefore, faunal assemblages should be used to monitor environmental changes (Danielopol, 1991b; Gibert, 1992).

The aquatic stygobitic fauna differs in composition from the surface-water fauna, owing to the absence of insects and to the dominance of crustacean species. In Europe, stygobitic species account for approximately 40% of the total crustacean fauna (Danielopol, 2000). At a global scale, 41% of crustacean orders have stygobiont representatives in ground waters, and 6 of the orders are essentially stygobionts (Mystacocarida, Gelyelloida, Syncarida, Mictacea, Thermosbenacea, Nectiopoda) (Stoch, 1995). For other crustacean groups such as Cyclopoida, Harpacticoida, Amphipoda, Isopoda and partly Ostracoda, the species richness in ground-water is near, or even higher than those recorded at comparable scales in surface freshwater habitats (Danielopol, 2000). There is also a large number of stygobitic relict species, which have became extinct in surface-water environments (Rouch and Danielopol, 1997).

The subclass Copepoda includes 10 orders (Huys and Boxshall, 1991), with over 11,500 known species (Humes, 1994). Only four orders (Cyclopoida, Calanoida, Harpacticoida, Gelyelloida) have free-living freshwater species. Harpacticoida are usually benthonic and rarely found in plankton. The order includes 53 families, but only Ameiridae, Canthocamptidae and Parastenocarididae are widely represented in freshwater habitats with about 1,000 species and subspecies (Dole-Olivier et al, 2000). The order Cyclopoida includes 12 families and is primarily marine epibenthic. It has secondarily invaded freshwater, mostly with the family Cyclopidae (Huys and Boxshall 1991), with 900 freshwater species and subspecies, mostly from the subfamilies Cyclopinae and Eucyclopinae. Calanoida are planktonic, occasionally found in benthic habitats of subterranean lakes or in karstic springs and within the hyporheos

In Eve L. Kuniansky, editor,2001, U.S. Geological Survey Karst Interest Group Proceedings, Water-Resources Investigations Report 01-4011, pp. 89-97

after floods (Dole-Olivier et al, 2000). Gelyelloida are represented by only two ground-water species in European karstic systems and from an undescribed interstitial stream habitat in South Carolina (Reid, pers. comm.). With more than 800 species/subspecies, a number surely underestimated, copepods inhabit all kinds of aquifers (karstic, fissured, porous), as well as surface/ground-water ecotones (land/water, water/water).

In general, crustaceans are extremely successful in colonizing ground water and in certain areas, hypogean species may be equal or exceed the number of epigean ones (Stoch, 1995). For example, detailed studies on the ground-water habitats in northeastern Italy and neighboring Slovenia, including the extremely developed karstic system showed that for copepods, 47.14% of the collected species were stygobiont. Nonetheless, the faunistic and taxonomic knowledge of ground-water organisms is rather scarce and species richness of stygobiont copepods is highly underestimated in several geographical areas. Moreover, there are usually few data on non-stygobites (i.e., stygophile: epigean organisms that occur in both surface water and ground-water without adaptation to subterranean life, stygoxene: typical epigean organisms that appear rarely, and mostly at random, in ground-water), organisms that are also needed to formulate a correct theory of hypogean species diversity. The biogeographical statement that stygobiont species are rare in tropical caves (Mitchell, 1969: Sbordoni, 1994) might be true for the Florida karstic system, but data are not in agreement with this statement (Rouch and Danielopol, 1987) and the knowledge of both stygobites and non-stygobites component of the fauna must be extended in order to support or reject these views. It must also be mentioned here that the species richness reported for a territory is related to the sampling effort. A comparison of the benthic copepod fauna shows that fewer than half as many species are known from North America as from Europe (Reid, 1992a), and the discrepancy is not due to a poorer fauna in North America, but to the lack in taxonomic studies (Reid, 1992a).

Several studies (see Rouch and Danielopol, 1997) show that extrapolating methods fail in determining species richness in ground water. A strong sampling effort is needed, together with a good knowledge of ecological/physical background data (Rouch and Danielopol, 1997). Moreover, within a given subterranean area, species richness of a taxocoenosys depends on the structure of the habitat and the functioning of the ecosystem within which these habitats are located: higher diversity can be expected in habitats that receive high quantities of energy and matter, e.g., the superficial aquifers close to surface water. Deep ground-water habitats (the "phreatic" ones) with their slower dynamics might have lower species richness (Rouch and Danielopol, 1997).

In Everglades National Park (ENP), the marl prairies of the Rocky Glades host plant and animal species adapted to variable hydroperiods, which has allowed some of them to survive the drainage of this region during the intensive development by agricultural and urban interests. Marl prairies are typically formed on a limestone karst substrate that provides a vertical dimension of habitat for aquatic organisms. In the Rocky Glades, the presence of solution holes and below-ground, near-surface habitat allows for survival of a greater variety of organisms. This is related to small differences among the different solution holes and because surface-dwelling aquatic organisms find refuge in the solution holes during the dry season (Loftus *et al*., 1992). The marl soils also retain some water and allow plants and animals to survive the drought. As a consequence, marl prairies still contain a very diverse community of plants and animals, some of which are endemic. The assessment of species composition in the marl prairies, and the following monitoring of changes in the communities appears to be of primary importance; the stress imposed over these habitats brings the risk of losing species, and of pushing to the point of extinction even organisms that can withstand large variations in physical habitat.
The transition area between the marshes and the Atlantic Coastal Ridge is also important to subterranean organisms, and this is one of the few areas where a gradient of surface/ground-water habitats is relatively intact. The surface-ground-water connections and interchange are much greater in this area than most geographic areas (based on faunal similarities), and the study of ground-water communities might give support to the necessity of protecting these areas in order to preserve ground water supplies.

The study of ground-water organisms in ENP is providing interesting preliminary results. Because it is the first time that ground waters in South Florida have been investigated for microcrustaceans, any collection is important in order to assess the species composition. Faunistic lists for ground-water organisms must be as complete as possible, and the ecology, biology and life cycle of each taxon has to be inspected and evaluated, for the purposes addressed above.

Ground-water organisms are comparatively protected from major climatic changes, and hypogean animals may persist in ground-water refugia; for the Everglades surface organisms, the possibility of entering the ground-water system can help them to survive the droughts. The identification of such surface organisms in ground water could therefore indicate a hydraulic connection between surface waters and the aquifer.

Monitoring the changes that might occur in the composition of ground-water communities can therefore be a useful tool in assessing changes in hydrology and water quality, particularly in ENP where major changes will be expected when the restoration projects are implemented.

MATERIALS AND METHODS

We selected a set of wells in each of the following areas (Fig. 1):

- Rocky Glades (13 wells)
- L31W-C111 canals, south-east of ENP (6 wells)
- Atlantic Coastal ridge northeast of ENP (15 wells)

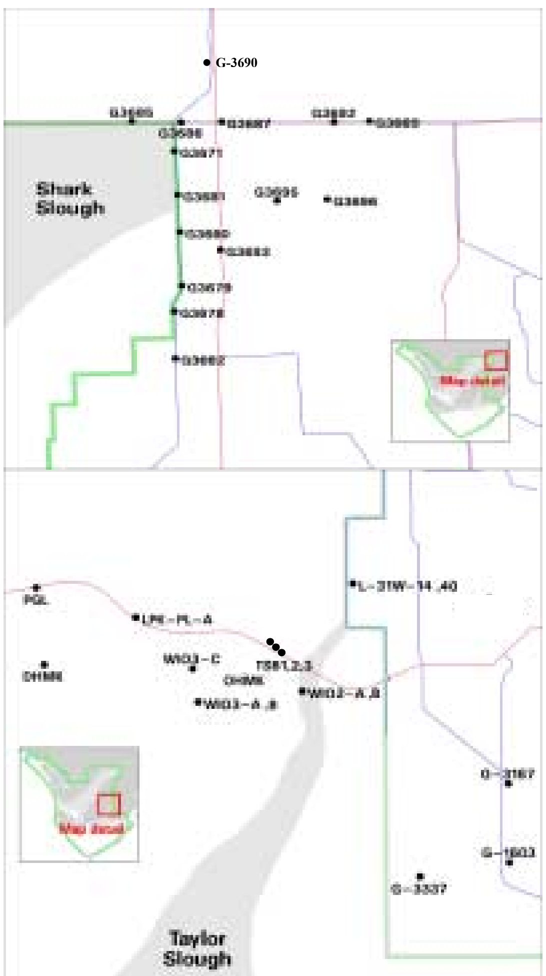

Figure 1 – Maps of sampling wells in the Atlantic Coastal Ridge Area (top), and in Rocky Glades/southeast of ENP (bottom)

Samples were collected monthly and, for the Atlantic Coastal ridge wells, cores and optical logs previously taken by USGS allowed sampling of different depths in each well, corresponding to highly permeable strata. For the wells in the Park area, we sampled on multiple depths, in order to reach high permeability layers.

A total of 91 samples have been collected monthly, starting in June 2000. In the Rocky Glades area, well PGL was flooded from June to October, OHMK and DHMK were flooded from July to September, LPK-PL-A and LPK-PL-B were flooded from August to September, and therefore all these wells were not sampled during these intervals. December samples form Atlantic Coastal Ridge wells were collected after a rainstorm that raised the water levels of about 10 cm.

Qualitative samples were collected using a Wayne® 1/2HP portable pump connected to a Coleman® 1750 Watt portable generator, and a set of 1.5 m long PVC pipe that were connected to the pump through a flexible plastic hose. 1,000 L of water were filtered using a 63-µm mesh, 20-cm-diameter plankton net. Water depth and environmental variables such as temperature, pH, conductivity, salinity, and dissolved oxygen were recorded using a YSI 85® Multi-Parameter Water Quality Meter.

All samples were fixed in the field with 5% buffered formalin; specimens were sorted and counted in the lab using a Leica® Stereoscope. Specimens of each taxa were mounted in permanent slides with Faure's medium and studied with a Leica® DMLS phase contrast microscope at 10X, 20X, 40X, 100X. All crustaceans were identified to at least family level, and for copepods the species, sex, and developmental stage have been determined. Results will be therefore presented only for this last group.

RESULTS

For the taxa collected, both species of calanoids, 22 of the 27 species of cyclopoids (81.5% of the species) and 2 of the 8 species of harpacticoids (25% of the species) (Reid, 1992b; Loftus and Reid, 2000; Bruno et al., 2000; Bruno et al., in press, Bruno unpubl. data) were present in the ground-water samples. Five cyclopoid species are new records for Florida, and one is the first record for North America.

At the beginning of the wet season, in June, when the groundwater level was still low (Figs. 2, 3), we collected copepods in quite good density, and the species number had the highest value (Fig. 4). Individuals were collected only in the first 9 m depth

In Eve L. Kuniansky, editor, 2001, U.S. Geological Survey Karst Interest Group Proceedings, Water-Resources Investigations Report 01-4011, pp. 89-97

(Fig. 5), with 56.8% at 0-3 m, 32.1% at 3-6 m, and 11.1% at 6-9 m (Fig. 6).

	0-3 m	3-6 m	6-9 m	9-12 m	> 12 m	Total	N
Jun.	0.515	0.291	0.101	0.000	0.000	0.907	17
Jul.	0.295	0.243	0.037	0.015	0.000	0.590	11
Aug.	0.175	0.188	0.122	0.002	0.003	0.490	12
Sep.	0.081	0.063	0.020	0.001	0.000	0.165	7
Oct.	0.705	0.078	0.039	0.000	0.000	0.822	13
Nov.	2.798	0.449	0.012	0.001	0.000	3.260	13
Dec.	0.124	0.211	0.039	0.003	0.002	0.379	10

Table 1- Density of individuals (N ind./L) collected at each depth class by month, and number of species per month.

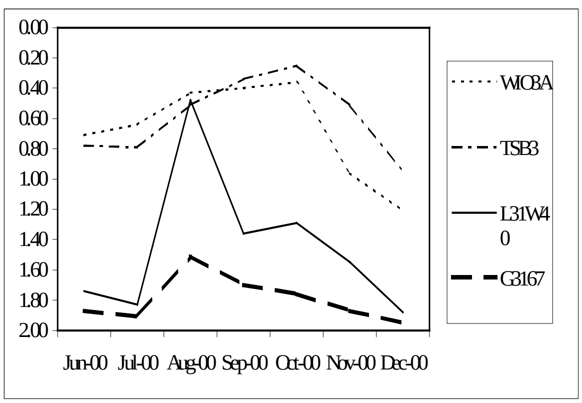

Figure 2 - Ground-water levels at selected Atlantic Coastal Ridge wells

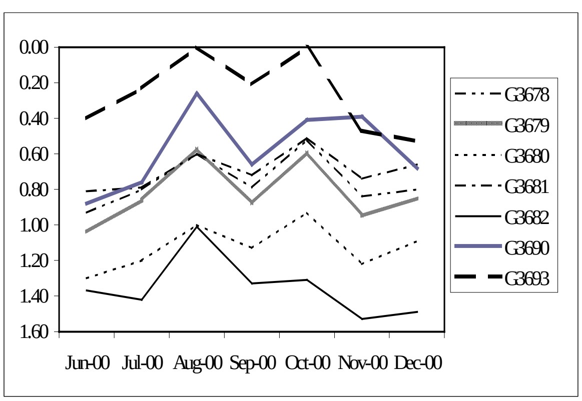

Figure 3 - Ground-water levels at selected Rocky Glades/south-east ENP wells

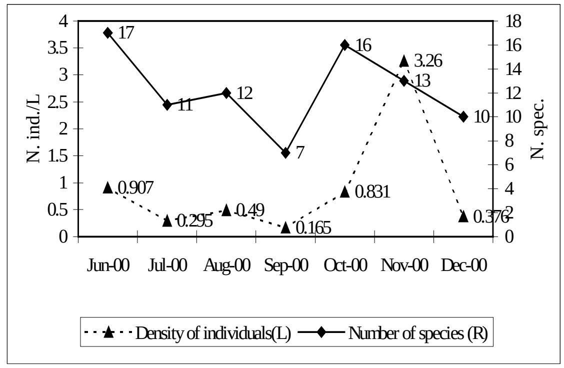

Figure 4 – Density of individuals (left) and of species (right) collected each month.

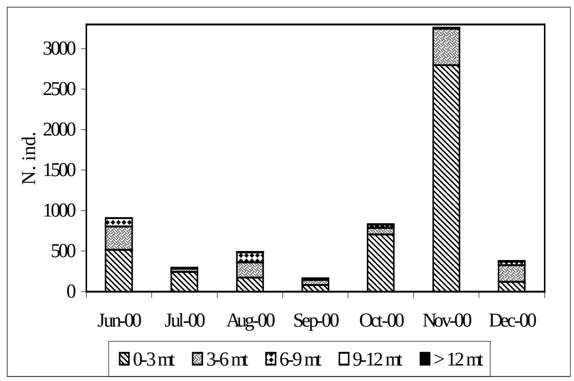

Figure 5 – Number of individuals collected at each depth class by month.

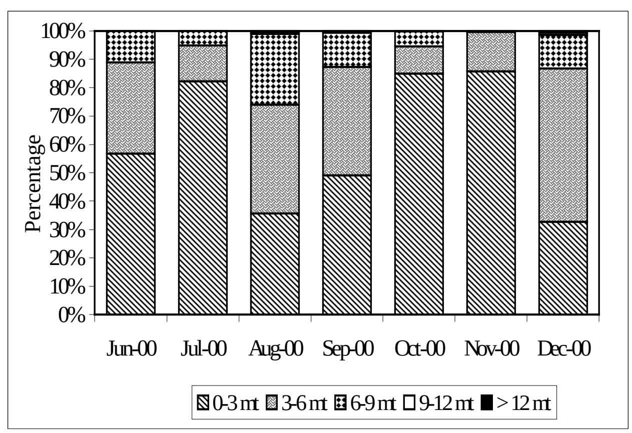

Figure 6- Percentage of individuals collected from each depth class, each month.

In August, in correspondence with high rainfall, the ground-water level was high at most sites (Figs 2,3), reaching almost the surface. In this month, the density of individuals was still low, and one more species was

In Eve L. Kuniansky, editor, 2001, U.S. Geological Survey Karst Interest Group Proceedings, Water-Resources Investigations Report 01-4011, pp. 89-97

recorded in respect to the previous month (Fig. 4, Tab. 1). For the first time, a few individuals were collected at depths below 12 m: 35.7% of the individuals were collected at 0-3 m, 38.4% at 3-6 m, 24.9% at 6-9 m, 0.4% at 9-12 m, and 0.6% at below 12 m (Figs. 5,6).

In September, ground-water level generally dropped (Figs. 2,3); both number of species and density of individuals had the lowest value (Figs. 4,5; Tab. 1). All individuals were collected at depths above 12 m, in particular: 49.1% at 0-3 m, 38.2% at 3-6 m, 12.1% at 6-9 m, and 0.6% at below 9 m (Fig. 6).

In October ground-water level rose again, due to extremely high rainfall (Fig. 2,3) and we recorded the highest species number (Fig. 4; Tab. 1) and densities of individuals since June. All specimens were collected at depths above 9 m, with 85.8% at 0-3 m, 9.5% at 3-6 m, and 4.7% at 6-9 m.

In November, at the end of the wet season, ground-water level dropped at most stations (Figs. 2,3), and the density of individuals was the highest recorded, more than three times higher than in October, but with less species (Fig. 4); most individuals were collected at shallow depths: 85.8% at 0-3 m, 13.8% at 3-6 m, and only 0.4% at 6-9 m (Figs, 5,6).

In December, when water level dropped (Fig. 4,5, data for Atlantic Coastal ridge wells were collected after a rainstorm (see materials and methods), and densities of individuals and number of species were low (Fig. 4; Tab. 1); 32.7% of the individuals occurred at 0-3 m, 55.7% at 3-6 m, 10.3% at 6-9 m, 0.8% at 9-12 m, and 0.5% at below 12 m (Figs. 5,6).

Regarding the ecology of the collected organisms, calanoids are planktonic species, therefore strictly epigean, and can be considered as stigoxene. Of the two species, *Arctodiaptumus floridanus* (Marsh 1926) was collected only in July with 83 individuals. The second species, *Osphranticum labronectum* (S.A. Forbes 1882), was collected through the entire sampling period with very few individuals until November, when we took 1,719 individuals. This species is usually very abundant in surface waters of ENP in the same time of the year (Bruno et al., submitted.).

Two species of cyclopoids, *Thermocyclops parvus* (Reid 1989) and *Diacyclops nearcticus* (Kiefer 1934), are associated with hypogean habitats and are stygophiles. Both had already been collected in ENP but mostly from ground water. A third species, a *Diacyclops* sp. very similar to *D. jeanneli* (Chappuis 1929), has been collected with only one specimen, therefore the taxonomic classification is still unsure, however *D. jeanneli* has only been collected in caves in Indiana. If *Diacyclops* sp. will is classified as *D. jeanneli*, it will be a new record for Florida of this stygobitic species. All other species of cyclopoids collected are epigean, but very euryoecious and tolerant of different physical-chemical conditions.

Of the two harpacticoids, *Phyllognathopus viguieri* (Maupas 1892) is one of the most widely distributed. It has been collected from virtually every possible freshwater habitat, ground water included (Dussart and Defaye, 1990). *Elaphoidella marjoryae* (Bruno and Reid 2000) had been previously collected both from ground waters and in solution holes during the dry season, when the deep solution holes that do not dry are connected and recharged by ground water (Bruno et al., 2000). This is therefore another species strictly related to ground-water habitats, and can probably be considered as stygoxene.

The trend in species richness and species composition is interesting, since the stygobite and stygophile species become very rare in September October. For example, we collected 38 specimens of *Diacyclops nearcticus* in August, 11 in September, and 10 in October, however, for this last month, this species was not present at all in the Rocky Glades wells, where it previously always occurred over the last 2 years of sampling. When the water level started to decrease, the number of individuals of *D. nearcticus* increased; we collected 67 individuals in November and 47 in December, most of them from the Rocky Glades wells. Other typically planktonic species are present in October, such as all species belonging to the genus *Paracyclops* and *Microcyclops*.

Regarding crustaceans other than copepods, we collected a few specimens of amphipods, isopods, and ostracods. Just two specimens of the isopod, *Caecidiotea* sp., were collected in good condition, and are being identified; the amphipods belonged to the genus *Crangonix*. Only a few ostracods were collected and were identified as both epigean, swimming forms, as well as hypogean, stygobitic species.

DISCUSSION

High diversity and densities of individuals would be expected in habitats that receive high inputs of energy and matter, as is the case of the superficial aquifers located closely to surface water. In the Rocky Glades area of the Everglades, a high degree of dissolution of the oolitic limestone bedrock has occurred with time, producing a typical karstic landscape with thousands of solution holes (Hoffmeister, 1974). Some of those are connected with ground water (Loftus et al. 1992). Surface organisms move to ground water to find a refuge from the drought and from predators (Loftus et al., 1992; Bruno et al., submitted.). Therefore, the presence of surface water organisms in our ground-water samples was expected. The dominance of strictly epigean taxa, such as calanoids, in ground-water samples, is indicative of surface-water intrusion in the aquifer, followed by passive dispersal of the organisms. Nonetheless, planktonic organisms are typically unable to actively move for long distances; their dimensions are often less than 1 mm, and therefore even the strongest swimmers (the largest species, such as calanoids) are limited in their dispersal abilities. We, therefore, assumed that species collected at a certain depth come from adjacent permeable layers.

Most of the specimens were collected in the USGS wells northeast of ENP, probably because we were sampling the high permeable layers. All those wells are along canals, and it is possible that planktonic organisms could enter ground water through lateral connections. In most of the ENP wells, surface organisms could be transported into the wells from the surrounding sloughs when the area is flooded during the wet season. Even if most of the copepods are not strictly epigean, they are able to survive in ground-water habitat and complete their life cycle there. In most months and wells, we collected individuals at different larval stages, suggesting that reproduction takes place in ground water for both epigean and hypogean taxa, or that both larval stages and adults can disperse in ground water and survive there.

The particular high diversity recorded in the shallow samples can be explained considering that the surface-water/ground-water interface sites are where intense hydraulic exchanges occur and the biogeochemical activity is higher than in the adjacent systems (Gibert et al., 1997). It has been assessed that the main characteristics of these interfaces are their great variety of elasticity, permeability, biodiversity and connectivity (Gibert et al., 1990). The marl prairies of the Rocky Glades have a high permeability (Fish and Stewart, 1992), allowing rapid surface/ground-water exchange. This happens particularly during the wet season, when ground waters are recharged by rainfall; surface organisms probably then disperse passively in ground water.

The wells may be divided in three groups: Atlantic Coastal Ridge, L-31W/C-111, and Rocky Glades. The first group always had the highest number of individuals, underlining the importance of using GPR and video cameras to locate permeable layers when ground-water colonization is studied in karstic habitats. In L-31W and C-111 wells, only few individuals were sporadically collected, even though these wells were located along canals, as in the previous group. We assume that the sampling depth did not correspond to highly permeable layers.

The Rocky Glades wells are not located along canals, but are in or very near areas that are flooded during the wet season. The exception are the TSB wells, that are on the main ENP road shoulder in the section crossing Taylor Slough, from which copepods might enter into ground water. The entire area has high permeability, with a transmissivity of about 300 ft^2/day (Fish and Stewart, 1992). Those wells had high numbers of individuals, with wide seasonal variations, and characteristic high numbers of calanoids, even when surface water had disappeared (e.g. PGL in November). Therefore, in this area surface copepods disperse into ground water and survive for long time, following the recession of the water table. The faunal assemblage of these wells was constituted by stygoxenes and by stygophiles, particularly *D. nearcticus, T. parvus,* and *Orthocyclops modestus* (Herrick 1883).

Our data may confirm the presence of seepage from the canals to the ground waters, at least for the wells along the Atlantic Coastal Ridge. These are mostly located on the sides of L-31N, L29, L30, and C-4 canals, and they are where most of the specimens were collected. For the Rocky Glades area, organisms may migrate vertically from surface waters, and when surface water disappears, they remain in ground-waters, since here they can not move back into the canals, as may be possible for organisms collected in the Atlantic Coastal Ridge wells. This seemed to happen particularly at the end of the wet season; in November, when the water table fell to deeper levels, calanoids survived by entering ground water, demonstrated by the high numbers (1,687) of individuals collected at PGL, a station that had been flooded until the previous month.

To our knowledge, faunistic exchanges in a karstic system such as the Everglades have never been studied. Nonetheless, data for other subterranean habitats raise the possibility of surface/ground-water exchanges, in relation to variation of ground-water levels. For example, Malard et al., 1994, found that ground-water communities were dominated by epigean organisms during low water periods when infiltration rates of surface waters were high. During periods of intensive ground-water recharge, these epigean organisms were displaced upstream and downstream of the study area and were also disseminated throughout the adjacent fissure network. They were associated with hypogean organisms, which were collected only when ground waters circulated though the opening of the site. Therefore, a close relationship existed between the ground-water flow, the movement of surface waters towards and within the aquifer, and the spatial and temporal distribution of hypogean and epigean species. Data from other ground-water habitats confirm this information. For example, Marmonier and Creuzé des Châtelliers (1991) studied the dynamics of interstitial assemblages after a spate and during low discharge, in a regulated channel of the Upper Rhône River. They found that most stygobites decreased in abundance or disappeared just after a spate while, during low discharge, stygobites were more abundant and diversified.

Ground-water ecosystems in the Everglades are diverse, and this diversity should be protected or even increased by ecological remediation procedures. As already stated by Rouch and Danielopol, 1997, species richness in subterranean habitats depends not only on the diversity of available habitats, but also on the global functioning of the ecosystems to which these habitats belong. Particularly important are the relationship between surface and subsurface systems. Therefore, in order to protect the subterranean fauna, the surrounding surface environment should be protected, since they are a component of the surface-subsurface hydrological exchanges.

In the Everglades, protection of the ground-water ecosystem will be achieved when environmental protection activities are finally extended to the entire system, to which this unique karstic habitat structurally and functionally belongs.

ACKNOWLEDGEMENTS

We wish to thank: E. Nance (SFNRC/ENP), C. Blanc (VIP/ENP), D. Riggs, H. Waddle, and A. Martin (USGS/BRD) for helping on the field, Dr. K. Cunningham (USGS/WRD) for geological information and for allowing us to use the Atlantic Ridge set of wells. Prof. D.L. Danielopol, Institute of Limnology, Austrian Academy of Sciences, identified Ostracods, Dr. Janet W. Reid, Natural Museum of Natural History, Smithsonian Institution, helped with copepod identification. Two anonymous referees improved the manuscript with their comments, and V. Foster assisted with editing.

The research was supported by South Florida Critical Ecosystem Science Initiative (CESI) funding to Dr. S. A. Perry. Funding for Dr. M. C. Bruno was provided by a Cooperative Agreement with Florida International University.

REFERENCES

Amoros, C. and J. Mathieu. 1984. *Structure et fonctionnement des écosystèmes du Haut-Rhône française. XXXV. Relations entre les eaux interstitielles et les eaux superficielles: influence sur les peuplements de Copépodes Cyclopoidës (Crustacés).* Hydrobiologia, 108: 273-280.

Bruno, M.C., J.W. Reid and S.A. Perry. 2000. *New records of copepods from Everglades National Park (Florida): description of two new species of Elaphoidella (Harpacticoida, Canthocamptidae), and supplementary description of Diacyclops nearcticus Kiefer (Cyclopoida, Cyclopidae*). Crustaceana 73 (10) in press.

Bruno M.C., W. F. Loftus, J. W. Reid, and S.A Perry. 2000. *Diapause in copepods (Crustacea) from ephemeral habitats with different hydroperiods in Everglades National Park (Florida, USA).* Proceedings of the 7th International Conference on Copepods, Curitiba, Brasil, 24-31 August 1999. Dev. Hydrobiol., in press.

Bruno, M.C., G. Sagnotti and S. A. Perry. 2001. *Copepod communities from marshes of different hydroperiods in Everglades National Park (Florida, U.S.A.), and relevance to restoration*. Subm. to Wetlands

Creuzé de Chatelliers, M. and J.-L- Reygrobellet. 1990. *Interactions between geomorphological processes, benthic and hyporheic communities: first results on a by-passed canal of the French upper Rhone River*. Reg. Riv., 5: 139-158.

Danielopol, D.L. 1989. *Groundwater fauna associated with riverine aquifers*. J. N. Am. Benthol. Soc., 8: 18-35.

Danielopol, D.L. 1991a. Spatial distribution and dsipersal of interstitial Crustacea in alluvial sediments of a backwater of the Danube at Vienna. Stygologia, 6: 97-110.

Danielopol, D.L . 1991b. *Ecological basic research with potential application for ground-water management. - Hydrobiological basis of ecologically sound management of soil and ground-water (Proceedings of Vienna Symposium).* IAHS Publication 202, p. 215-228.

Danielopol, D.L. 2000. *Biodiversity in groundwater: a large-scale view.* TREE, 15: 223-224.

Dole-Olivier, M.J. and P. Marmonier. 1992. *Patch distribution of interstitial communities: prevailing factors*. Freshwater. Biol., 27: 177-191.

Dole-Olivier, M.J., D.M.P. Galassi, P. Marmonier and M. Creuzé des Châtelliers. 2000. *The biology and ecology of lotic microcrustaceans*. Freshwater. Biol., 44: 63-91.

Dussart, B. H. and D. Defaye. 1990. *Répertoire mondial des Crustacés Copépodes des eaux intérieures. III. Harpacticoïdes*. Crustaceana, (Suppl.) 16: 1- 384.

Fish, J.E. and M. Stewart. 1992. *Hydrology of the surficial aquifer system, Dade County, Florida*. U.S. Geological Survey Investigation Report 90-4108, 50 pp.

Gibert, J. 1992. *Ground-water ecology in a perspective to environmental sustainability.* Proceedings of the first international conference on ground-water ecology. *A.W.R.A*, Tampa, Florida, p. 3-13.

Gibert, J., M.-J. Dole-Olivier, P. Marmonier and P. Vervier. 1990. *Ground-water ecotones*, in R.J. Naiman and H. Décamps, eds., *Ecology and management of aquatic-terrestrial ecotones*. Paris-London, Man and the Biosphere Series Unesco, and Parthenon Publishing Carnforth, p. 199-225

Gibert, J., F. Fournier and J. Mathieu. 1997. *The ground-waters/surface water ecotone perspective: state of the art*, in Gibert J., Fournier F. and J. Mathieu, eds., *Ground-water/surface water ecotones: biological and hydrological interactions and management options.* Cambridge Univ. Press,Cambridge UK, p. 3-8,

Humes, A.G. 1994. *How many copepods?* Hydrobiologia 292/293, 1-7.

Hoffmeister, J.E. 1974. *Land from the Sea*. Univ. of Miami Press, Coral Gables, Florida, 143 pp.

Huys, R. and G. Boxshall. 1991. *Copepod Evolution*. The Ray Society, London.

Lafont, M. and A. Durbec. 1990. *Essai de description biologique des interactions entre eau de surface et eau souterraine: vulnérabilité d'un aquifère a la pollution d'un fleuve*. Annls. limnol., 26: 119-129.

Loftus, W.F., R.A. Johnson and G. H. Anderson. 1992. *Ecological impacts of the reduction of groundwater levels in short-hydroperiod marshes of the Everglades,*IN J.A. Stanford and J.J. Simons eds., *Proceedings of the First International Conference on Groundwater Ecology*. American Water Resources Association, Bethesda, Maryland: 199-208.

Loftus, W.F. and J.W. Reid. 2000. *Copepod (Crustacea) emergence from soils from Everglades marshes with different hydroperiods*. J.Fresh. Ecol. 15(4): 515-523.

Malard, F., J.-L. Reygrobellet, J. Mathieu and M. Lafont. 1994. *The use of invertebrate communities to describe groundwater flow and contaminant transport in a fractured rock aquifer*. Arc. Hydrobiol., 131: 93-110.

Marmonier, P. and M. Creuzé de Chatelliers. 1991. *Effectes of spates on interstitial assemblages of the Rhône River. Importance of heterogeneity.* Hydrobiologia, 210 : 243-251.

Mitchell, R.W. 1969. *A comparison of temperate and tropical cave communities*. S. W. Natural., 14 (1):73-88.

Reid,J.W. 1992a. *Taxonomic problems: a serious impediment to ground-water ecological research in North America*. in J. Simons and J. Stanford, eds., *Proceedings of the First International Conference on Ground Water Ecolog, U.S. E.P.A., A.W.R.A. Washington D.C.,* p. 133-142.

Reid, J.W. 1992b. *Copepoda (Crustacea) from fresh waters of the Florida Everglades, U.S.A., with a description of Eucyclops conrowae n. sp*. Trans. am. microsc. Soc. 111: 229-254.

Rouch, R. 1991. *Structure du peuplement des harpacticoides dans le milieu hyporhéique d'un reisseau des Pyrenees.* Annl. Limnol., 27: 227-241.

Rouch, R. and D.L. Danielopol. 1987. *L'origine de la faune aquatique souterraine, entre le paradigme du refuge et le modèle de la colonisationa ctive.* Stygologia, 3(4): 345-372.

Rouch, R. and D.L. Danielopol. 1997. *Species richness of Microcrustacea in subterranean freshwater habitats. Comparative analysis and approximate evaluation*. Int. Revue, ges. Hydrobiol., 82: 121-145.

Sbordoni, V. 1994. *Cave system in Chiapas (Mexco): a theatre for evolutionary plays and the shaping of biodiversity.* XIth Int. Symp. Biospeleol., Florence, Italy, 13-14.

Stoch, F. 1995. *The ecological and historical determinants of Crustacean diversity in groundwaters, or: why are there so many species*? Mém. Biospéol. 22: 139-160.