Letter to Editor

Survival of *Ceriodaphnia dubia* (Crustacea, Cladocera) Exposed to Different Screens Against Natural Ultraviolet Radiation

P. De Los Rios[1]*, P. Acevedo[2], K. Verdugo[1]

[1]Universidad Católica de Temuco, Facultad de Recursos Naturales, Escuela de Ciencias Biológicas y Químicas, Casilla 15-D, Temuco, Chile
[2]Universidad de la Frontera, Facultad de Ingeniería, Ciencias y Administración, Departamento de Ciencias Físicas, Casilla 54-D, Temuco, Chile

Received: May 30, 2006
Accepted: November 10, 2006

Abstract

The current increase of penetration of natural ultraviolet radiation (UVR) in southern South America affects water bodies because the UVR can penetrate the water column. In this scenario, the zooplankton develops photoprotective strategies such as vertical migrations against UVR or synthesis of photoprotective substances. The present study was done using a population of *Ceriodaphnia dubia*. that was collected from small shallow wetland near Temuco, Chile. The specimens were exposed for 7 to 9 hours to natural ultraviolet radiation, and with different colored nylon as protection against UVR, the experiment was done during the southern summer of 2006. The results revealed that in the presence of protection against UVR provided by colored nylon, the mortality was low, whereas under exposure to UVR and covering by transparent nylon total mortality was observed. The relation between mortality and the dose of UV that can penetrate the different colored nylon is represented by LC_{50} in UV (280-400 nm) and UVB (280-320 nm), within intensities of 234.82 and 14.96 kJ/m^2, respectively.

Keywords: ultraviolet radiation, *Daphnia* spp., dissolved organic carbon, wetlands

Introduction

An increase of natural ultraviolet radiation (UVR) is currently described for South America, which is due to stratospheric ozone depletion [1]. The UVR would affect freshwater ecosystems because it can penetrate the water column under conditions of absence of natural screens such as dissolved organic carbon [2]. The aquatic fauna under conditions of exposure to natural UVR generates photoprotective strategies such as negative phototaxis against UVR [1, 3, 4], or synthesis of photoprotective or antioxidant substances, such as carotenoids, mycosporine-like aminoacids, and melanine or ascorbic acids [1, 5]. Many of these studies have dealt with crustacean zooplankton species such as *Daphnia* spp for the northern hemisphere or with *Boeckella* genera for the southern hemisphere [6-10]. Many of the studied species inhabit lakes of great depth or shallow ponds [1, 9, 11, 12]. The literature descriptions explain that UVR-B is the most harmful fraction within UVR radiation for aquatic fauna, mainly zooplankton species, whereas the UVR-A has little effect, because the UVR-A and visible light generate activation photoprotective responses [1, 8, 13]

In central southern Chile there are numerous wetlands between 37-40° southern latitude that are characterized

*Corresponding author; e-mail: prios@uct.cl

by flooding during the winter rains. Some of these wetlands are ephemeral, with a dissecation period in summer. Unfortunately there are no published studies about aquatic microinvertebrates of these water bodies. These water bodies are shallow (Z < 6 m) and characterized by the presence of submerged macrophytes such as *Juncus* spp [14] that would provide shelter against UVR for the aquatic microinvertebrates [15], because otherwise probably the UVR radiation would penetrate in whole water column. The aim of the present study is to expose individuals of a cladoceran found in small wetlands to natural UVR under different artificial protective colored nylon.

Material and Methods

The specimens of *Ceriodaphnia dubia* were collected in a small wetland within Temuco (38°42'9.42" S – 72°32'47.92" W). The organisms used in the present experiment were identified according to literature descriptions [16]. The specimens were acclimated for four days using water collected in Villarrica Lake (Bay of Villarrica town; 39°16'51.29" S – 72°13'14.37' W), that is characterized by an oligo-mesotrophic status and high transparence and penetration of UVR of the water column and predominance of daphnids [17]. These conditions would indicate that Villarrica lake would provide optimal conditions to sustain abundant daphnid populations, including the species such as *C. dubia* [16], and in previous experiences with water from Villarrica Lake (Bay of Villarrica town), these natural medium provide optimal conditions for sustain daphnid specimens such as *C. dubia* (personal observations). The experimental design consisted of two experiments, with exposure and protection, respectively, by colored nylon against UVR. The first experiment included the following treatments: exposure to natural UVR, covered by transparent, orange and yellow nylon. The experiment began at 09:00 and finished at 18:00 on 25th January 2006. Also, the second experiment included the following treatments: exposure to UVR, orange and yellow nylon; this experiment began at 10:00 and finished at 17:00 on 26th January 2006. The experimental set up was done by foam plastic as the bottom with small pieces of wood to support a plastic cover 5 cm above. Between the bottom and the plastic cover from the Petri dishes of 1 cm high and 10 cm diameter were placed and filled with 30 ml of water from the Villarrica Lake, keeping a constant volume, and three Petri dishes were used in each treatment. Each experimental unit was inoculated with ten specimens, and the dead specimens were counted at the end of each experimental period. The experiments were performed in the Meteorological Station of the Mathematical and Physical Sciences Department of the Catholic University of Temuco.

For the study period, solar ultraviolet radiation for Temuco (dose and maximum intensity), and that transmitted by different colored nylon (Table 1), was measured in situ with a spectroradiometer Li-Cor model 1800. Table 1 lists the transmittance of different nylon (transparent, orange and yellow) used in the present study, in the three cases the values of the transmittance remain constant for all the interval from 280 to 400 nm. These different kinds of nylon were used to decrease UVR irradiance that affected the treatments. The data obtained with the spectroradiometer included spectral radiation between 300 and 1100 nm, measured each 1 nm. The spectroradiometer is calibrated according to the indications of the National Bureau of Stantards (NBS) of the Unites States of America. Extrapolation is used to calculate radiation UV between

Table 1. Transmittance of different nylon used during the present study for UV and UVB.

Nylon	Transmittance	
	UV	UVB
Transparent	0.810	0.788
Yellow	0.070	0.086
Orange	0.170	0.154

Table 2. Average % mortality, standard error, dose and maximum UV for 280-400 nm and 280-320 nm, for each treatment used during the present study.

Date	Treatment	Dose UV 280-400 nm (kJ/m²)	Dose UVB 280-320 nm (kJ/m²)	Maximum UV 280-400 nm (W/m²)	Maximum UVB 280-320 nm (W/m²)	% mortality
25th January 09:00–18:00 hrs	Exposed	1622.9	95.4	57.0	3.7	100 ± 0
	Transparent	1314.4	75.2	46.2	2.9	100 ± 0
	Yellow	113.8	8.3	4.0	0.3	50 ± 12
	Orange	275.8	14.8	9.7	0.6	50 ± 6
26th January 10:00 – 17:00 hrs	Exposed	1382.8	84.2	58.2	3.9	100 ± 0
	Yellow	96.8	7.2	4.1	0.3	17 ± 3
	Orange	235.1	13.0	9.9	0.6	40 ± 15

280 and 300 nm (this radiation corresponds to around 3% of total UVB). To obtain the relationship between the percentage of mortality (LC_{50}) of the specimens and the UV dose, were applied a regression analysis, using Statistica 5.0 software.

Results and Discussion

The results showed denoted a high mortality of specimens during the experimental period under conditions of high exposure to natural ultraviolet radiation, with treatments of exposure to UVR and covering with transparent nylon (Table 2). Conversely, we found low mortality under conditions of low exposure to UVR in treatments of coverage with orange and yellow nylon (Table 2). A regression analysis revealed the existence of a significant logarithmic trend between percentage of mortality with dose of UVR and maximum UVR for 280-320 nm (Fig.1 a, c) and 280-400 nm, respectively (Figs.1 b, d).

The results of LC_{50} for UV dose, in 280-400 nm and 280-320 nm, were 234.82 kJ/m^2 and 14.96 kJ/m^2, respectively. Thus, the present study revealed that the species used is vulnerable to exposure to UVR, which agrees with similar results obtained for other southern freshwater zooplanktonic crustaceans [7-10, 18]. The logarithmic trend obtained in the present study is similar to descriptions in the literature [6, 8, 19]. Similar short-term experiments [19] with different levels of exposure to natural UVR for *Daphnia longispina* and *D. pulex* at Arctic latitudes revealed high mortality at 2000 kJ/m^2. One need contrast these results with field observations of behavior patterns in response to UVR considering potential interactions such as the role of submersed macrophytes as refuge, that probably would be related to horizontal migrations to littoral zones [15]. Other interactions that are not studied would be effects of alterations at community level [10], and effects of possibly present humic substances (dissolved organic matter) that would act as a natural screen against UVR to protect zooplankton species [20-23]. In

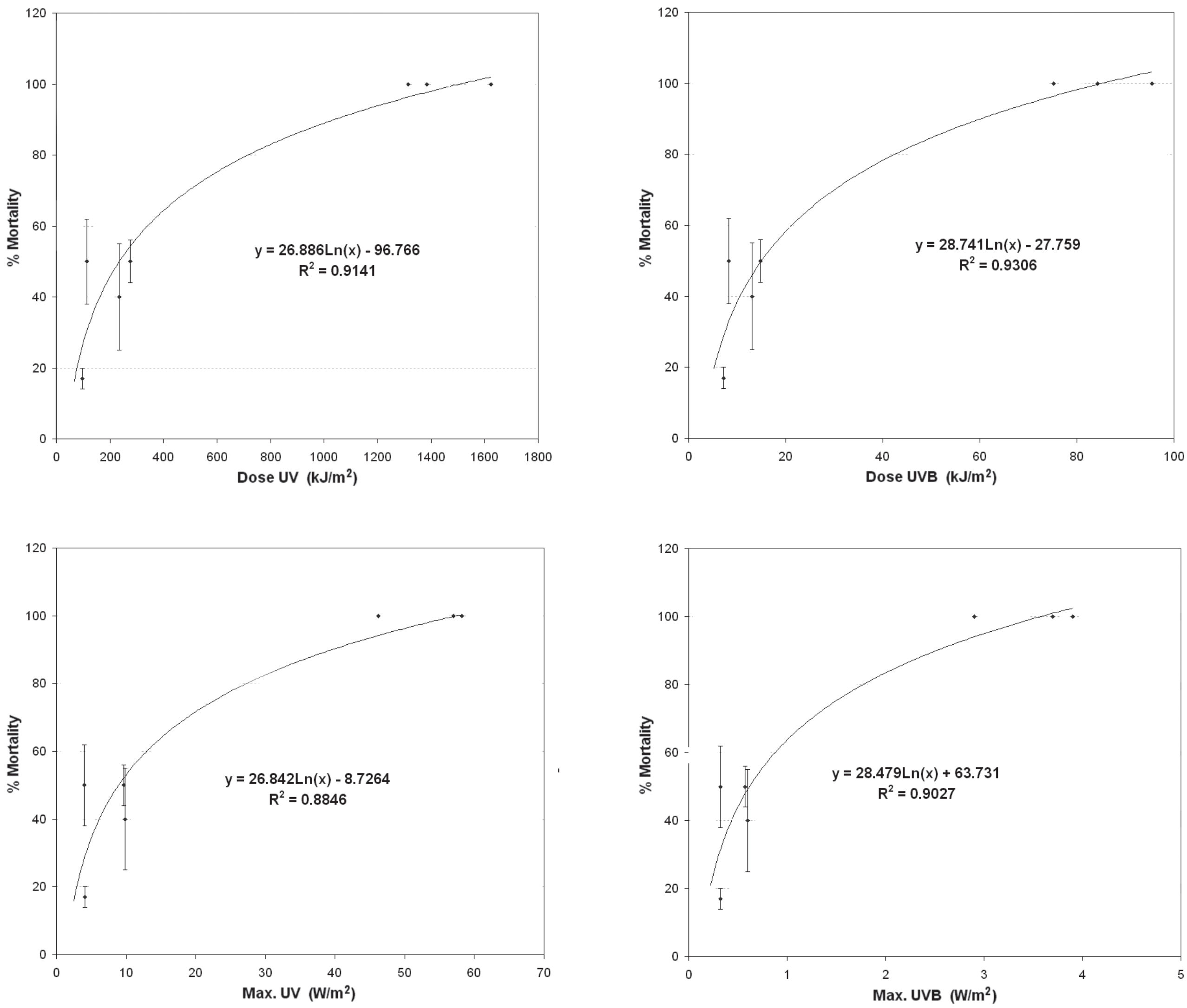

Fig. 1. Results of regression analysis for experiments done in the present study, between: (a), (b) mortality% and UV and UVB dose; (c), (d)% mortality and UV and UVB maximum.

wetland and shallow lakes the presence of submersed macrophytes generates dissolved organic matter, which under UVR exposure leads to photobleaching of dissolved organic matter, a situation generating a labile substances that enhances bacterial productivity [24-26], or formation of oxidant substances [22]. Unfortunately there are not studies of freshwater microcrustaceans in southern Chilean wetlands. It is important to study the effects of high exposure to UVR in Chile [27], because exposure to UVR is a potential threat to microcrustaceans, which are an essential resource sustaining endangered migratory aquatic birds that use the wetlands of central southern Chile as feeding areas [14].

Aknowledgements

The present study was financed by projects of the Research Directorate of the Catholic University of Temuco, Chile, and "Proyecto DIUFRO 120614 de la Dirección de Investigación y Desarrollo, Universidad de La Frontera, Temuco, Chile." The assistance of Vicente Sandoval, Mario Ramirez and Jose Luis Barahona by the access facilities of the Meteorological Station of Catholic University of Temuco is also gratefully acknowledged.

References

1. VILLAFAÑE, V.E., E.W. HELBLING, H.E. ZAGARESE. Solar ultraviolet radiation and its impact on aquatic ecosystems of Patagonia, South America. Ambio. **30**, 112, **2001**.
2. MORRIS, D.P., ZAGARESE H.E., WILLIAMSON C.E., BALSEIRO E.G., HARGREAVES B.R., MODENUTTI B.E., MOELLER R.E., C.P. QUEIMALIÑOS. The attenuation of solar UV radiation in lakes and the role of dissolved organic carbon. Limnol. Oceanogr. **40**, 1381, **1995**.
3. STORZ, U.C., R.J. PAUL. Phototaxis in water fleas (*Daphnia magna*) is differently influenced by visible and UV light. Journ. Comp. Physiol. (A) **183**, 709, **1998**.
4. ALONSO, C., ROCCO V., BARRIGA J.P., BATTINI M.A., ZAGARESE H. Surface avoidance by freshwater zooplankton: field evidence on the role of ultraviolet radiation. Limnol. Oceanogr. **49**, 225, **2004.**
5. ROCCO V.E., OPPEZZO O., PIZARRO R., SOMMARUGA R., FERRARO M., ZAGARESE H.E. Ultraviolet damage and countering mechanism in the freshwater copepod *Boeckella popei* from Antarctic peninsula. Limnol. Ocean **47**, 829, **2002**
6. ZAGARESE, H.E., FELDMAN, M., WILLIAMSON, C.E. UV-B-induced damage and photoreactivation in three species of *Boeckella* (Copepoda: Calanoida). J. Plankt Res. **19,** 357, **1997**.
7. ZAGARESE, H.E., CRAVERO W., GONZALEZ P., PEDROZO, F. Copepod mortality induced by fluctuating levels of natural ultraviolet radiation simulating vertical water mixing. Limnol. Ocean. **43**, 169, **1998**.
8. TARTAROTTI B., CRAVERO W., ZAGARESE H.E. Biological weighting for the mortality of *Boeckella gracilipes* (Copepoda, Calanoida) derived from experiments with natural solar radiation. Photochem. Photobiol. **72**, 314, **2000**.
9. DE LOS RÍOS P., Survival or pigmented freshwater zooplankton exposed to artificial ultraviolet radiation and two concentrations of dissolved organic carbon. Polish Journ. Ecol. **53**, 113, **2005.**
10. DE LOS RIOS P., SOTO D. Survival of two species of crustacean zooplankton under two chlorophyll concentrations and protection from or exposure to natural ultraviolet radiation. Crustaceana **78** 163, **2005**.
11. DE LOS RÍOS P., SOTO. D. Structure of the zooplanktonic crustaceous Chilean lacustre assemblages: role of the trophic status and protection resources. Crustaceana **79**, 23, **2006**.
12. SOTO D., DE LOS RÍOS P. Trophic status and conductivity as a regulators in daphnid dominance and zooplankton assemblages in lakes and ponds of Torres del Paine National Park. Biologia Bratislava. (in press).
13. GRAD G., WILLIAMSON C.E., KARAPELOU D.M. Zooplankton survival and reproduction responses to damaging to UV radiation: a test of reciprocity and photoenzymatic repair. Limnol. Ocean. **46,** 584, **2001.**
14. HAUENSTEIN E., GONZÁLEZ M., PEÑA-CORTÃS F., MUÑOZ-PEDREROS A. Clasificación y caracterización de la flora y vegetación de los humedales de la costa de Toltén (IX región, Chile). Gayan. Bot. **59**, 87, **2002**.
15. BURKS R.L., LODGE D.M., JEPPENSEN E., LAURIDSEN T.L. Diel horizontal migration of zooplankton: costs and benefits of inhabiting the littoral. Freshwater Biology **47**, 343, **2002**.
16. ARAYA, J.M., ZUÑIGA, L.R. Manual taxonómico del zooplancton lacustre de Chile. Copepods. Boletín Informativo Limnológico, [In Spanish.] **8**, 1, **1985.**
17. DE LOS RÍOS, P. Efectos de las disponibilidades de recursos energéticos, estructurales y de protección sobre la distribución y abundancia de copépodos y cladóceros zooplanctónicos lacustres chilenos. Tesis de Doctorado, Universidad Austral de Chile, Facultad de Ciencias. [In Spanish with English abstract.] pp. 1-107, **2003.**
18. DE LOS RÍOS, P. Lethal effects of ultraviolet radiation under different concentrations of dissolved organic carbon on *Neobosmina chilensis* (Daday, 1902) (Cladocera, Bosminidae). Crustaceana **8**, 989, **2004**
19. ZELLMER, I.D. The impact of food quantity on UV-B tolerance and recovery from UV-B damage in *Daphnia pulex*. Hydrobiologia **319**, 87, **1996**.
20. RAUTIO M., KORKHOLA, A. Effects of ultraviolet radiation and dissolved organic carbon on the survival of subarctic zooplankton. Pol. Biol. **25**, 460, **2002**.
21. RAUTIO, M. Zooplankton assemblages related to environmental characteristics in treeline ponds in Finnish Lapland. Arct. Ant. Alp. Res. **33**, 289, **2001**.
22. HESSEN D.O., BORGERAAS J., ORBAEK J.O. Responses in pigmentation and antioxidant expression in Arctic *Daphnia* along gradient of DOC and UV exposure. J. Plank. Res. **24**, 1009, **2002**.

23. LEECH, D.M, WILLIAMSON C.E. Is tolerance to UV radiation in zooplankton related to body size, taxon or lake transparency? Ecol. Appl. **10**, 1530, **2001**.
24. FARJALLA V.F., ANESIO A.M., BERTILSSON S., GRANELLI W. 2001. Photochemical reactivity on aquatic macrophyte leachates: abiotic transformations and bacterial response. Aq. Microb. Ecol. **24**, 187, **2001**.
25. GRANELLI W., LINDELL M., MARCAL DE FARIA B., ESTEVES F. Photoproduction of dissolved organic carbon in temperate and tropical lakes – dependence on wavelength band and dissolved organic carbon concentration. Biogeochemistry **43**, 175, **1998.**
26. RECHE I., PACE M.L., COLE J.J. Modeled effects of dissolved organic carbon and solar spectra on photobleaching in lake ecosystems. Ecosystems **3**, 419, **2000**.
27. CABRERA S., BOZZO S., FUENZALIDA H. Variations in UV radiation in Chile. J. Photoch. Photob. B. Biol. **28**, 137, **1995**.