Latinmag Letters, Volume 9, Special Issue (2019), C01-O, 1-6. Proceedings Rancagua, Chile

ROCK MAGNETIC STUDIES ON TWO SEDIMENT CORES FROM LAKE MELINCUÉ, ARGENTINA

R. Achaga[1]*, C.S.G. Gogorza[1], M.A. Irurzun[1], A. Gogichaishvili[2], D. Martinez[1], A. C. Ruiz Fernandez[3], J. A. Sánchez Cabeza[3], A. Sinito[1], J. Morales[2]

[1] Centro de Investigaciones en Física e Ingeniería del Centro de la Provincia de Buenos Aires (CIFICEN), Universidad Nacional del Centro de la Pcia. de Bs. As. (UNCPBA) - Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Tandil, Argentina - Centro de Investigaciones en Física e Ingeniería del Centro de la Provincia de Buenos Aires (CICPBA), Tandil, Argentina.

[2] Laboratorio Interinstitucional de Magnetismo Natural (LIMNA), Instituto de Geofísica, Unidad Michoacán, Campus Morelia, UNAM, Morelia, México.

[3] Unidad Académica Mazatlán, Instituto de Ciencias del Mar y Limnología (ICML), UNAM, Mazatlán , México.

*e-mail: romi.achaga@gmail.com

ABSTRACT

Laguna Melincué is a shallow lake located in the central Pampean Plains of Argentina. This lake has been previously studied from different approaches, but more multidisciplinary studies are needed to understand its complex hydrological situation. Rock-magnetic studies on two cores: Lme 16-2-1 and Lme 16-2-2, collected from the center of the lake are presented in order to identify paleoclimatic proxies. The longest one (Lme 16-2-1) was selected to make ^{210}Pb dating and XRF studies. On Lme 16-2-2 measurements of natural remanent magnetization (NRM), alternating field (AF) demagnetization, anhysteretic remanent magnetization (ARM), isothermal remanent magnetization and its saturation (IRM and SIRM, respectively) and lithology description were made. Magnetic susceptibility (k) was used to correlate both cores. Rock magnetic analyses suggest that magnetic mineralogy is dominated by (titano) magnetite and/or maghemite, and possibly also greigite. As a first estimate of relative magnetic grain-size variations, the median destructive field of the ARM (MDF_{ARM}) and SIRM (MDF_{SIRM}) were determined. The changes in magnetic grain size and concentration of magnetic minerals indicate environmental variations and changes at the lake level consistent with historical reports. High resolution environmental analysis aims to obtain conclusion about the relationship between floods and agricultural exploitation in the area.

Keywords: Pampean Plains, Lake sediments, Rock-magnetism, Paleoenvironmental studies.

RESUMEN

La Laguna Melincué es una laguna somera que se encuentra en el centro de la llanura Pampeana de la Argentina. Esta laguna ha sido previamente estudiada desde diferentes enfoques, pero se necesitan más estudios multidisciplinarios para entender su compleja situación hidrológica. Se presentan los resultados del magnetismo de rocas de dos testigos (núcleos) de sedimento: Lme 16-2-1 y Lme 16-2-2, provenientes del centro de la Laguna Melincué, con el objetivo de contribuir en la identificación de proxies paleoclimáticos. El de mayor longitud (Lme 16-2-1) fue seleccionado para realizar dataciones de ^{210}Pb y estudios de XRF. En el Lme 16-2-2 se realizaron mediciones de magnetización remanente natural (MRN), desmagnetización por campos alternos (AF), magnetización remanente anhistérica (MRA), magnetización remanente isotermal y su saturación (MRI y MRIS, respectivamente) y descripción litológica. La susceptibilidad magnética (k) se utilizó para correlacionar ambos testigos. Los análisis de magnetismo de roca sugieren que la mineralogía magnética está dominada por (titano) magnetita y/o maghemita, y también la posible presencia de greigita. Como primera estimación de las variaciones relativas del tamaño del grano magnético, se determinó el campo destructivo medio de la MRA (CDM_{MRA}) y de la MRIS (CDM_{MRIS}). Los cambios en el tamaño del grano y la concentración de los minerales magnéticos indicarían variaciones ambientales y cambios en el nivel de la laguna que están de acuerdo con registros históricos. El análisis ambiental de alta resolución tiene como objetivo obtener una conclusión sobre la relación entre las inundaciones y la explotación agrícola en el área.

Palabras clave: Llanura Pampeana, Sedimentos lacustres, Magnetismo de rocas, Estudios paleoambientales.

1. Introduction and study site description

Lake sediments are good sources of paleomagnetic and paleoclimatic variations because they provide continuous record. Every change in the catchment area (rainfall and drought periods, temperature changes, difference of sedimentation rates, etc.), as well as, changes in the Earth magnetic field are reflected in the variations of directional and non-directional magnetic parameters (Maher and Thompson, 1997). In particular, variations in concentration, mineralogy and magnetic grain size are used to characterize the sediments. Previous studies of Lake Melincué include a shore core by Achaga *et al.* (2017). In this work we present rock-magnetic results and dating studies in central cores.

Lake Melincué (33°41'27.8'' S, 61°31'36.5'' O) is located in Santa Fe Province, Argentina. The actual catchment area is around 678 km^2. The basin is in a tectonically sunken block and hydrologically the lake is considered a closed basin, without important tributaries or effluents of permanent flow. The mean annual precipitation is about 970 mm with the highest precipitation during austral autumn. The mean temperatures have an annual variation between 9.5° C and 24° C in winter and summer, respectively (Pasotti *et al.*, 1984).

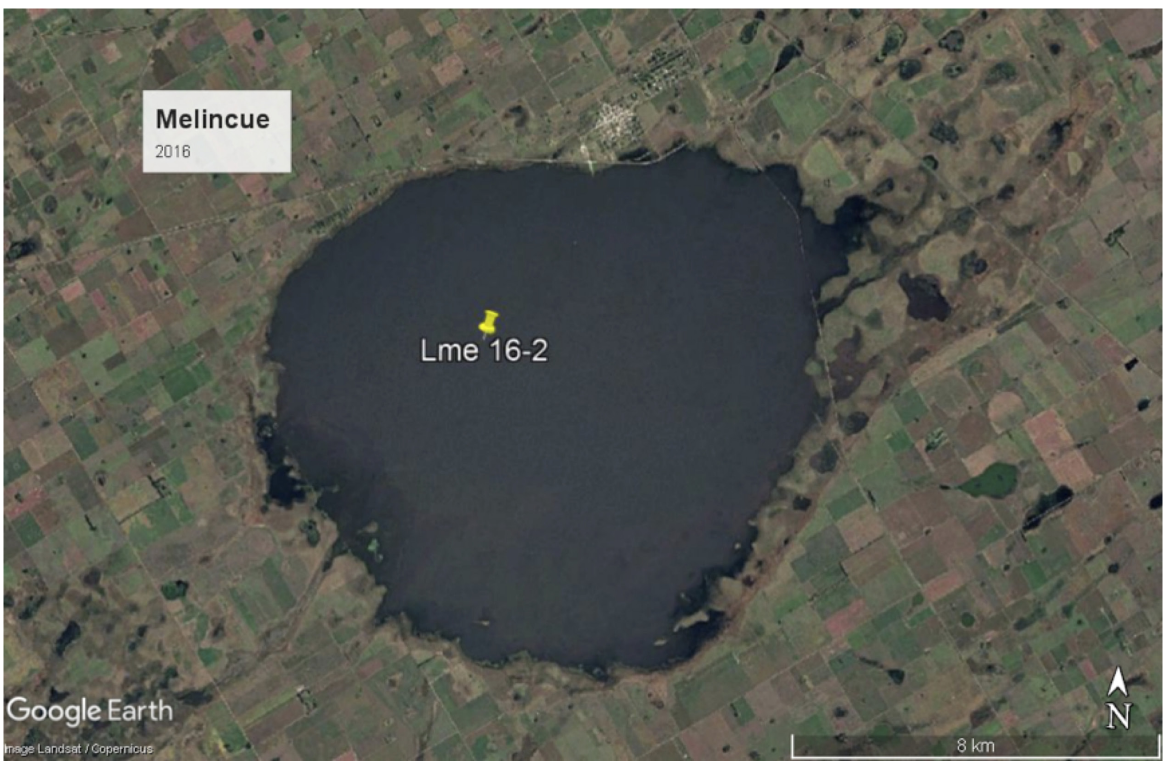

Figure 1. Aerial photo of Laguna Melincué (Google Earth) showing the location of the coring site used in this work (central cores).

2. Methodology

Two cylindrical cores Lme 16-2-1 and Lme 16-2-2 were collected in October 2016 from the same site in Lake Melincué, their size was 6-cm diameter and they had approximately 4 m-depth (Figure 1). k was measured every 1 cm on core Lme16-2-1 (length 57.5 cm) using a Bartington MS2C to identify general trends. ^{210}Pb measurements in the first 36 cm of the core and XRF studies in the entire core were made in the Instituto de Ciencias del Mar y Limnología, México. In order to date the entire core, the age was extrapolated using a model sedimentation rate calculated from the ^{210}Pb dating. Figure 2 shows the ages modeled with this procedure for Lme 16-2-1.The ages were transferred to the other core using k logs correlation.

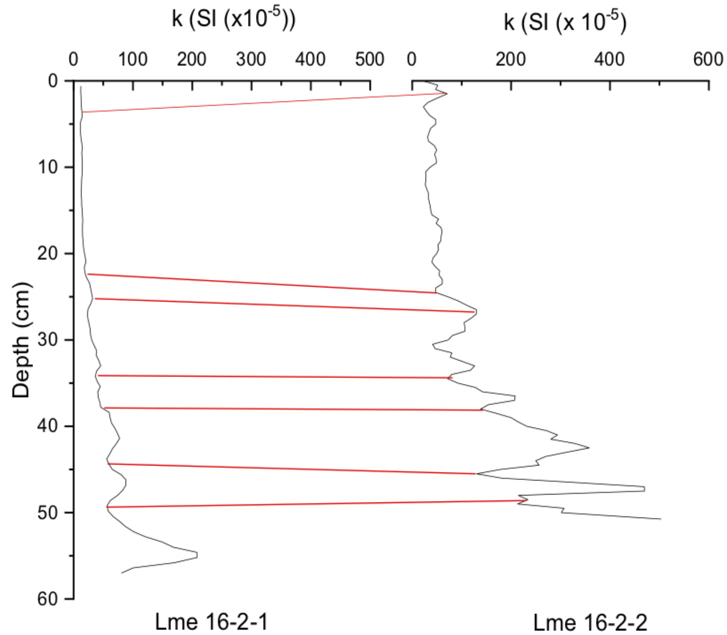

Figure 2. Correlation tie lines of k logs from the cores Lme16-2-1 and Lme16-2-2

Lme 16-2-2 was split in two halves for lithological description and k measurements. k values were taken every 0.5 cm with a Bartington MS2E. After that, the core was stored in a cool room at 4° C. The core was sub-sampled with cubic plastic boxes (20 mm × 20 mm × 20 mm) that were pushed into the surface of the open core face. A total of 22 samples were obtained for rock magnetic analysis. A set of laboratory experiments were carried out on every sample to obtain a magnetic characterization of the sediments. k of cubic specimens was measured at 0.47 kHz (k_{low}) and 4.7 kHz (k_{high}), respectively, using a Bartington MS2 Magnetic Susceptibilimeter. These values were used to calculate the relative frequency-dependent susceptibility, F = (k_{low}- k_{high}) / k_{low}, expressed in %. The stability of the NRM was analyzed by AF demagnetization using an AF demagnetizer (Molspin Ltd.). The samples were demagnetized successively at peak fields of 5, 10, 15, 20, 25, 30, 35, 40, 50, 60 and 100 mT. The ARM was acquired in an AF peak of 100 mT and a direct current (DC) biasing field of 0.05 mT using the same AF demagnetizer with a pARM device (Molspin Ltd.). IRM was acquired at room temperature in increasing steps until 1.2 T, reaching the saturation (SIRM) and in increasing steps in back fields until 300 mT using an IM-10-30 Pulse Magnetizer (ASC Scientific). Subsequently, AF demagnetization of the ARM and the SIRM were made following the same steps as for the NRM demagnetization. Associated parameters S_{ratio} (-$IRM_{300\ mT}$ / SIRM), remanent coercive field (B_{CR}), SIRM / k, ARM / k and ARM / SIRM were calculated. All remanent magnetizations were measured with a JR6A Dual Speed Spinner Magnetometer.

3. Results

Sediment accumulation rates were estimated from their vertical concentration profiles of the radioisotopes ^{210}Pb on core Lme16-2-1. At 10.5 cm an age AD 1998 ± 1 was determined, so a mean sedimentation rate of 6.1 mm/yr is suggested. At 20.5 cm an AD age 1974 ± 3 and a mean sedimentation rate of 4.1 mm/yr was determined. The oldest date, AD 1900 ± 4, was determined at 36.5 cm suggesting a sedimentation rate of around 2.2 mm/yr. The ages were extrapolated using a sedimentation rate of 2.2 mm/yr in order to estimate the date of the entire core. Basal ages of AD 1805 and of AD 1832 were obtained for Lme 16-2-1 and Lme 16-2-2, respectively. The changes in the sedimentation rate can be due to different agricultural lands uses and/or to climate changes (Irurzun *et al.*, 2014a). Figure 2 shows the correlations tie lines between cores using k logs.

From the lithological analysis of Lme 16-2-2, three sedimentary units were found representing different environmental conditions. k, NRM, ARM and SIRM logs of Lme 16-2-2 showing the lithological units (U1, U2 y U3) and its corresponding ages are shown in Figure 3. k and SIRM logs show variations with correspondence in peaks and troughs. NRM and ARM differ from k and SIRM especially in U1 unit. The median destructive field of the ARM varies from 14.3 to 16.4 mT for U1 unit, from 16.5 to 20.1 mT for U2 unit and from 18 to 21.3 mT for U3 unit. The median destructive field of the SIRM varies from 12.6 to 14.4 mT for U1 unit, from 13.4 to 15.2 mT for U2 unit and from 10.8 to 13.4 mT for U3 unit, respectively. Besides, the magnetic grain-size parameters SIRM/k and ARM/SIRM show higher values from bottom to top, which indicate finer magnetic grains size towards the present (Turner, 1997). The SIRM vs. k log also shows that the magnetic grain size decreases from U3 to U1 (Figure 4). The SIRM/k vs. B_{CR} log suggests that the magnetic mineralogy is dominated by titano-magnetite and/or maghemite. Similar results were reported by Achaga *et al.* (2017) (Figure 4).

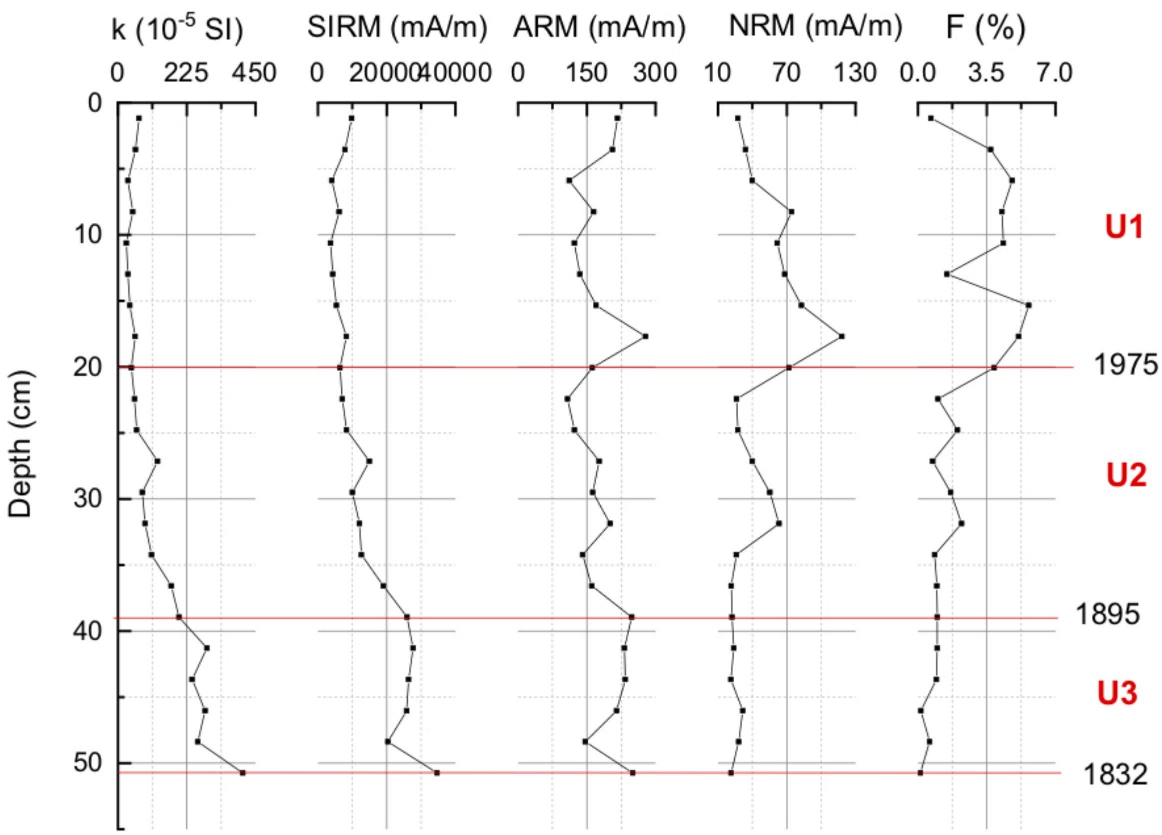

Figure 3. k, SIRM, ARM and NRM logs of Lme 16-2-2.

Coarser magnetic grain-size in U3 unit would indicate lower water level during this period. This could be related to the end of the Little Ice Age (LIA) when dry and cold conditions affected the Pampas region (Laprida and Valero-Garcés, 2009). According to concentration parameters (k and SIRM), U2 unit seems to be a transition zone. F also indicates a trend from coarser to finer magnetic grain size in this unit. The most conspicuous difference between remanences and k are observed in U1. Parameters more sensitive to the presence of finer single-domain (SD) grains (NRM, ARM) are higher that parameters that are sensitive to coarser multi-domain (MD) and pseudosingle-domain (PSD) grains (k, IRM). A large increase of F (Figure 3) with values near 5% would indicate the presence of SP grains, suggesting sulfate reduction. Anaerobic degradation of organic matter in marginal and pelagic sediment environments is known to cause dissolution of detrital magnetic minerals and authigenic growth of iron sulfides (Rowan, 2009). All this indicate progressive dissolution of MD and PSD magnetite and the possible formation of SP/SD greigite. The demagnetization of the NRM (not shown) shows the presence of gyroremanence in some samples also supporting the presence of SD greigite. The variation of the magnetic grain size and the possible formation of greigite is related to and increased in the lake level and the installation of wet conditions. This agrees well with a huge inundation that was documented in Melincué in 1978.

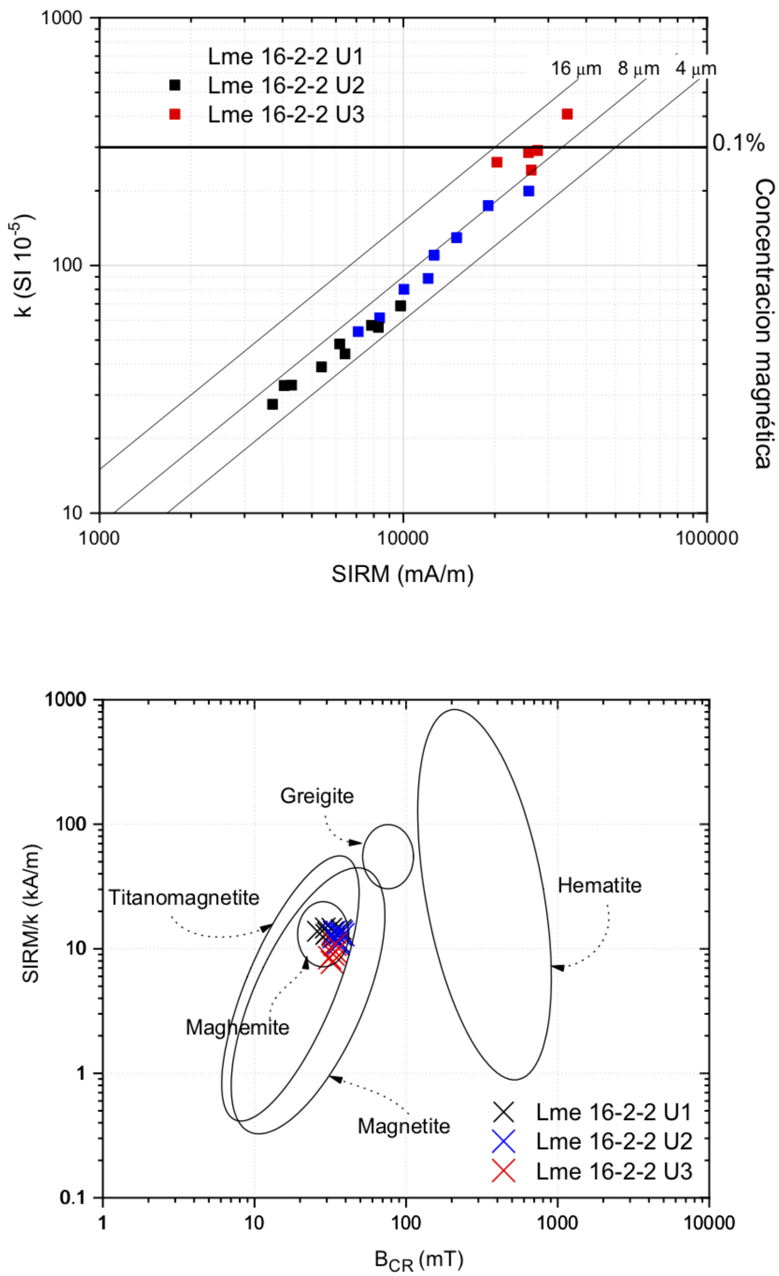

Figure 4. k vs. SIRM and SIRM/k vs. B_{CR} logs that are indicators of magnetic grain-size and mineralogy respectively.

4. Conclusion

The studied cores show a similar behavior in k logs allowing a good correlation. Rock-magnetic analysis seems to follow the lithological changes suggesting that the observed variations could be due to changes in grain size and/or changes in mineralogy. Basal ages of AD 1805 and AD 1832, were obtained for Lme 16-2-1 and Lme 16-2-2, respectively. The magnetic mineralogy is dominated by titano-magnetite and/or maghemite, although in U1 unit the dissolution of MD and PSD magnetite and the large content of organic matter could indicate the possible formation of greigite. Further scanning electron microscope (SEM) observations are needed to elucidate this question.

References

Achaga, R.V., Irurzun, M.A., Gogorza, C. S., Sinito, A. M., Goguitchaichvili, A.; Morales, J., Loponte D., 2017. Paleomagnetic and paleoclimatic investigation at Laguna Melincue (Pampean Plains, Argentina): preliminary results. *Studia Geophysica et Geodaetica 61, 318-335.*

Irurzun, M. A., Gogorza, C. S., Sinito, A. M., Chaparro, M. A. E., Prieto, A. R., Laprida, C., Lirio, J. M., Navas, A. M., Nuñez, H., 2014a. A high resolution paleoclimate record for the last 4800 cal. years B.P. on Lake La Brava SE Pampa plains, Argentina; Elsevier; *Geofísica Internacional 53,* 4, 11-2014*;* 365-383.

Irurzun, M. A., Orgeira, M. J., Gogorza, C. S., Sinito, A. M.; Compagnucci, R., Zolitschka, B., 2014b. Magnetic parameters and their paleoclimatic implications the sediment record of the last 15500 cal. BP from Laguna Potrok Aike (Argentina); Wiley; *Geophysical Journal International 198;* 2; 6-2014; 710-726.

Laprida C.; Valero Garcés B. 2009. Cambios ambientales de épocas históricas en la pampa bonaerense en base a ostrácodos: historia hidrológica de la laguna de Chascomús. *Ameghiniana 46;* 95-111.

Maher, B.A, Thompson, R. 1999. Quaternary Environments, Climates and Magnetism. *Cambridge University Press. 231-278*

Pasotti P., Albert O., Canoba C., 1984. Contribución al conocimiento de la laguna Melincué. *Facultad de Ciencias Exactas e Ingeniería, Universidad Nacional de Rosario, Rosario, Argentina, 31.*

Rowan, C. 2009.Reductive diagenesis, magnetite dissolution, greigite growth and paleomagnetic smoothing in marine sediments: A new view. *Earth and Planetary Science Letters 277*, 223-235.

Turner, G. 1997. Environmental magnetism and magnetic correlation of high resolution lake sediment records from Northern Hawke's Bay, New Zealand. *40,* 3, 287-298.