J. Great Lakes Res. 27(3):384–391
Internat. Assoc. Great Lakes Res., 2001

NOTE

First Finding of the Amphipod *Echinogammarus ischnus* and the Mussel *Dreissena bugensis* in Lake Michigan

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ABSTRACT. *The first finding of the amphipod* Echinogammarus ischnus *and the mussel* Dreissena bugensis *in Lake Michigan is documented. These two species are widespread and abundant in the lower lakes, but had not yet been reported from Lake Michigan.* E. ischnus *is generally considered a warm-water form that is typically associated with hard substrates and* Dreissena *clusters in the nearshore zone. Along the eastern shoreline of Lake Michigan, this species was present at rocky, breakwall habitats along the entire north-south axis of the lake. Although not abundant, this species was also found at soft-bottomed sites as deep as 94 m in the southern basin. The finding of this species in deep offshore waters apparently extends the known habitat range for this species in the Great Lakes, but it is found in deep water areas within its native range (Caspian Sea).* D. bugensis *was not abundant, but was present in both the southern and northern portions of the lake. Individuals of up to 36 mm in length were collected, indicating that it had probably been present in the lake for 2 or more years. Also presented are depth-defined densities of* D. polymorpha *at 37 sites in the Straits of Mackinac in 1997, and densities at up to 55 sites in the southern basin in 1992/93 and 1998/99. Mean densities decreased with increased water depth in both regions. Maximum mean density in the Straits in 1997 was 13,700/m^2 (≤ 10 m), and maximum density in the southern basin in 1999 was 2,100/m^2 (≤ 30 m). Mean densities at the ≤ 30-m interval in the southern basin remained relatively unchanged between 1993 and 1999, but increased from 25/m^2 to 1,100/m^2 at the 31 to 50 m interval over the same time period.* D. polymorpha *was rare at sites > 50 m. The presence of* E. ischnus *and the expected population expansion of* D. bugensis *will likely contribute to further food-web changes in the lake.*

INDEX WORDS: *Nonindigenous species, amphipod, quagga mussels, zebra mussels, Lake Michigan.*

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INTRODUCTION

The introduction and rapid spread of various invasive species in the Great Lakes over the past few decades have led to wide-scale ecological changes (Mills *et al.* 1994, MacIsaac 1996, Nalepa *et al.* 1999, Johannsson *et al.* 2000). The extent of these changes has varied depending upon the specific physical characteristics of the habitat, and life history patterns of the particular invader. With this in mind, we document the expansion and initial distributions of two invasive species in Lake Michigan that will likely contribute to ongoing food-web changes. The two species, *Echinogammarus ischnus* and *Dreissena bugensis*, are abundant and widely distributed in the lower lakes, but thus far have not been reported from Lake Michigan. *E. ischnus* is a benthic amphipod that was first reported from the Detroit River in fall 1995 (Witt *et al.* 1997), but was likely present in the western basin of Lake Erie as early as 1993 (van Overdijk 2000). This species spread eastward, and by 1997 was found in the eastern portion of Lake Ontario and in the St. Lawrence River (Dermott *et al.* 1998). The other species, the bivalve *D. bugensis* (quagga mussel), was first reported in eastern Lake Erie in late 1989, and by 1993 had spread throughout Lake Ontario and as far west as the western basin of Lake Erie (Mills *et al.* 1999). *D. bugensis* had not been reported from regions of the Great Lakes west of Lake Erie, or from the upper lakes, despite intensive sampling efforts for dreissenids in Saginaw Bay, Lake St. Clair, and southern Lake Michigan in the early and mid-1990s (Nalepa *et al.* 1995, 1996, 1998). This species, however, has been reported in the Mississippi and Ohio Rivers (Mills *et al.* 1996, Brence and Miller 1994).

Most invasive species introduced into the Great Lakes system over the past few decades have been reported first from the lower lakes (Lakes St. Clair, Erie, and Ontario) and then rapidly spread into Lake Michigan. Examples include *Dreissena polymorpha* (zebra mussel) (Marsden *et al*. 1993), *Neogobius melanostomus* (round goby) (John Janssen, University of Wisconsin-Milwaukee, personal communication), and *Cercopagis pengoi* (fishhook water flea) (Charlebois *et al.* 2001). The spread of these species into Lake Michigan was likely facilitated by boat traffic and the interlake transport of ballast water by shipping vessels. Given this dispersal pattern, the expansion of both *E. ischnus* and *D. bugensis* into Lake Michigan from the lower lakes was expected. In the case of *D. bugensis*, even though surveys indicate a gradual, systematic dispersal pattern through the lower lakes, there is evidence to suggest that boat-mediated dispersal is also occurring (Wilson *et al.* 1999). In this note, initial abundances and distribution patterns of these two species are documented, and evidence of a new habitat range for *E. ischnus* in the Great Lakes is provided. Recent densities and depth distributions of *D. polymorpha* are also given.

METHODS AND MATERIALS

Samples examined for both *E. ischnus* and *D. bugensis* were collected at various locations/habitats throughout the lake using several different methods. In the southern basin, samples were collected in triplicate with a Ponar grab at up to 55 sites in May, July, and September/October in 1992, 1993, 1998, and 1999 (Fig. 1). Water depth at these sites ranged from 16 to 154 m. Exact coordinates for 40 of the sites are given in Nalepa *et al.* (1985); the other 15 sites were focused in the southeastern portion of the lake and sampled only in spring and fall, 1998 and 1999 (coordinates available upon request). Triplicate grab samples were also collected at 37 sites in the Straits of Mackinac in August 1997 (Fig. 1). Water depth at these sites ranged from 4 to 66 m, but most sites had a water depth ≤ 10 m (19 of 37). Samples collected in both regions were washed through a 500-µm mesh Nitex net and the residue preserved in 5% formalin containing rose bengal stain. In the laboratory, organisms were picked under a 1.5 × magnifier lamp, counted, and sorted by major taxonomic group. Besides providing density estimates of *E. ishnus* and *D. bugensis*, these samples also provided density estimates of *D. polymorpha*. To examine depth distributions, sites in both regions were placed into depth intervals and mean densities determined for each interval. Intervals in the southern basin were ≤ 30 m, 31 to 50 m, 51 to 90 m, and > 90 m; these intervals are consistent with other macroinvertebrate studies in the southern basin (Nalepa *et al.* 1998). Intervals in the Straits were ≤ 10 m, 11 to 20 m, 21 to 30 m and > 30 m.

In addition to Ponar collections, samples specific for *E. ischnus* were collected using a long-handled D-net (500-µm mesh) at rocky breakwalls near harbor mouths at Michigan City, St. Joseph, Muskegon, Ludington, Frankfort, and Charlevoix in October 1999, and at Waukegan in December 1999 (Fig. 1). The net was hand swept between the limestone boulders and along the boulder interfaces at

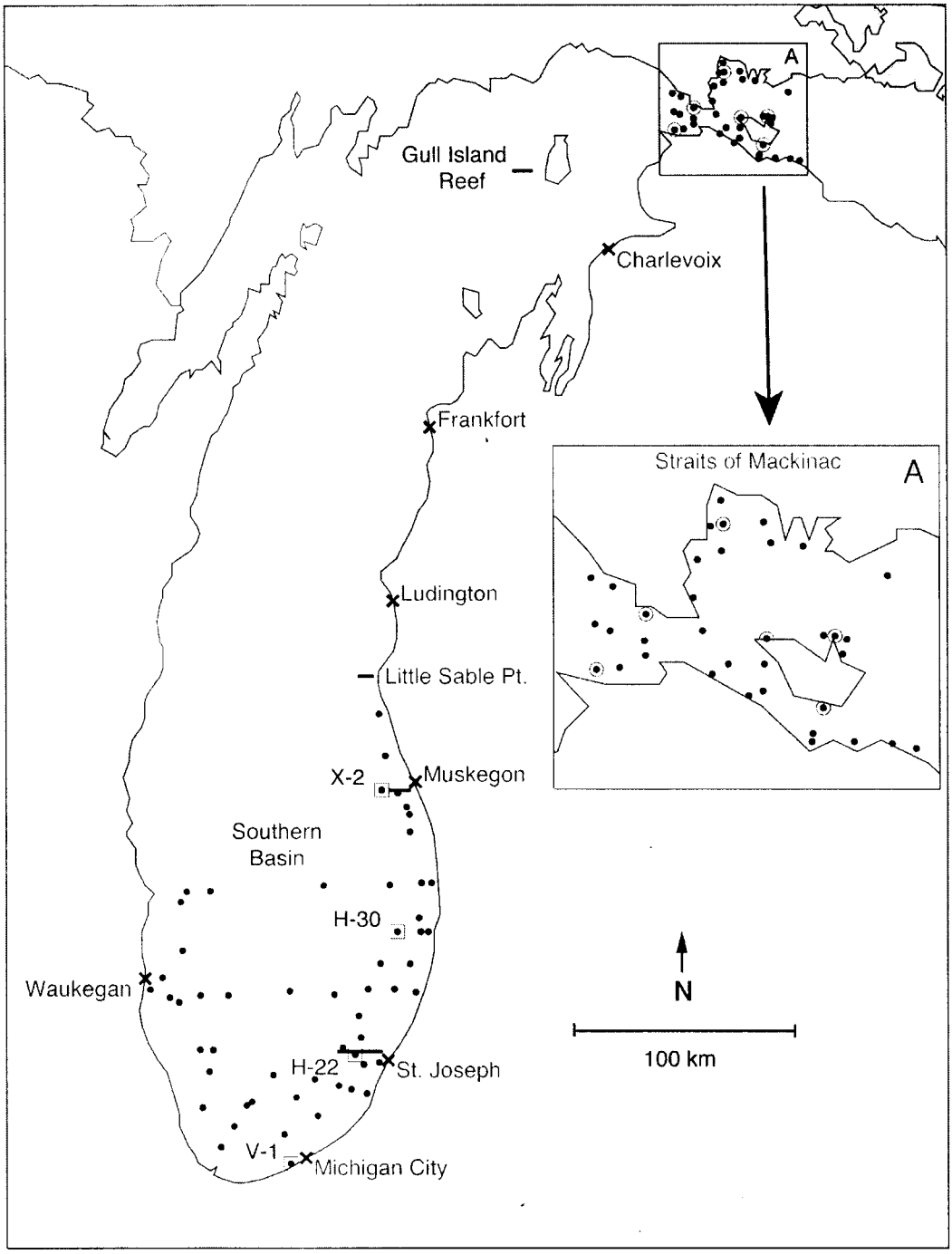

FIG. 1. Location of sampling sites for* Echinogammarus ischnus, Dreissena bugensis, *and* D. polymorpha *in Lake Michigan. Sites where grab samples were taken are indicated by a dot (•); shoreline sites where D-net samples were taken specifically for* E. ischnus *indicated by an X; and locations of trawl tows are indicated by a bar (-). Grab-sample sites enclosed by a square are sites where* E. ischnus *was found, and those sites enclosed by a circle are sites where* D. bugensis *was found. Insert A is an expanded view of the Straits of Mackinac.

TABLE 1. Mean (± SE) density (per m²) of amphipod taxa and dreissenid taxa in each of four depth intervals in the Straits of Mackinac in August 1997. The value in parentheses is the number of sites in each depth category where each taxa was collected. **Echinogammarus ischnus** ***was not found at any of the sites.***

Depth Interval (m)	Number of Stations	Amphipod Taxa			Dreissenid Taxa	
		Diporeia spp.	*Gammarus* sp.	*Hyallela* sp.	*D. polymorpha*	*D. bugensis*
≤ 10	19	280 ± 125 (11)	80 ± 28 (12)	85 ± 71 (10)	13,673 ± 5,446 (18)	4 ± 2 (6)
11–20	8	701 ± 319 (7)	42 ± 25 (4)	35 ± 29 (4)	10,535 ± 8,443 (8)	0 ± 0 (0)
21–30	6	459 ± 452 (4)	25 ± 25 (1)	44 ± 44 (1)	1,580 ± 682 (6)	0 ± 0 (0)
> 30	4	5,012 ± 2,273 (4)	0 ± 0 (0)	0 ± 0 (0)	230 ± 230 (1)	0 ± 0 (0)

each site. This method was not quantitative, but was useful to document present/absence and distribution patterns of this species along the north/south axis of the lake.

Other samples examined included *Dreissena* incidentally collected with a 7.6 m semi-balloon bottom trawl (13 m stretch cod-liner) while towing for fish at depths between 20 and 80 m along the eastern shoreline off St. Joseph, Muskegon, and Little Sable Point (Fig. 1). *Dreissena* was also collected incidental to surveys for juvenile lake trout with a beam trawl towed at 8–22 m depth on Gull Island Reef in the northern portion of the lake (Fig. 1). All trawl collections were made in July/August 2000. For each trawl haul that collected *Dreissena*, a representative subsample was immediately frozen and later examined for relative numbers of *D. bugensis* and *D. polymorpha*.

RESULTS

Of the sites sampled with a Ponar grab in the southern basin, *E. ischnus* was first collected at a site (H-22) off St. Joseph in July 1998 (Fig. 1). This site was at 45-m water depth and had a soft bottom (silt). Six individuals were found in one of the triplicate grab samples at this site, and these were the only individuals collected in 1998. In September 1999, *E. ischnus* was found at three sites, V-1, H-30, and X-2 (Fig. 1). Water depths at these sites were 16, 77, and 94 m, respectively, and bottom substrates consisted of silty sand at the shallowest site, and silt at the two deep sites. Only a few individuals were found at the two deep sites, but *E. ischnus* was abundant and clearly associated with a cluster of *D. polymorpha* in one of the replicates at the 16-m site. Densities of *E. ischnus* in the three replicate samples taken at station V-1 were 4,391/m², 0/m², and 0/m², and corresponding densities of *D. polymorpha* in the same samples were 56,356/m², 43/m², and 1,242/m², respectively. *E. ischnus* was not found at any of the 37 sites sampled in the Straits of Mackinac in August 1997; amphipod taxa that were present included *Diporeia* spp., *Gammarus* sp. and *Hyallela* sp. (Table 1).

E. ischnus was present at all rocky habitats sampled with the D-net. Based on subjective estimates of catch per unit effort, this species was most abundant at sites in the southern portion of the lake (Michigan City, St. Joseph), and least abundant at the northern site (Charlevoix). Individuals varied in size at all sites, ranging from 1.5 to 9 mm in body length. Based on examining at least 200 individuals from each site except the Charlevoix site (only 34 individuals collected), no amphipod taxa other than *E. ischnus* were present.

D. bugensis was present at 6 of the 37 sites sampled in the Straits of Mackinac in 1997 (Table 1). All six sites were ≤ 10 m in water depth. Collected individuals were < 13 mm in shell length, and maximum density at a given site was 14/m². This species was not found in any of the grab samples taken in the southern basin between 1992 and 1999.

Only three specimens of *D. bugensis* were found in trawl tows in July/August 2000 despite the large number of dreissenids collected and examined (Table 2). Single individuals were found in the southern (off St. Joseph), central (off Muskegon), and northern (Gull Island Reef) regions of the lake. These individuals were < 10 mm in shell length, except for the individual collected near Muskegon, which was 30 mm in length. In other bottom trawl samples in which collected dreissenids were examined specifically for *D. bugensis* (non random selection), this species was found off Little Sable Point (at 74 m). Also, individuals of up to 36 mm in

TABLE 2. Relative numbers of* D. polymorpha *and* D. bugensis *from a random subsample of dreissenids incidentally collected in trawl tows at various locations and depths in Lake Michigan. Trawling occurred to depths of up to 80 m at St. Joseph, Muskegon, and Little Sable Point. Only those trawl tows with collected* Dreissena *are given.

Location and Depth	*D. polymorpha*	*D. bugensis*
St. Joseph		
25 m	3,304	1
35 m	868	0
Muskegon		
25–27 m	8,496	1
45 m	3,968	0
65 m	1,888	0
Little Sable Point		
20 m	3,008	0
45 m	6,944	0
Gull Island Reef		
8 m	645	1

shell length were found off Little Sable Point and at Boulder Reef (reef near Gull Island Reef).

D. polymorpha was most abundant and widely distributed at the shallowest depth intervals in both the southern basin and in the Straits. In the southern basin, mean densities at the ≤ 30 m and 31 to 50 m depth intervals in 1999 were 2,056/m^2 and 1,059/m^2, respectively (Table 3). Over the period between 1993 and 1999, densities were generally unchanged at the ≤ 30 m interval, but increased dramatically (42-fold) at the 31–50 m interval. This species was rarely found at depths > 50 m over the entire sampling period. In the Straits, *D. polymorpha* was present at 33 of the 37 sites sampled, and mean densities were greatest in the ≤ 10 m and 11 to 20 m depth intervals (Table 1).

DISCUSSION

In Europe, *E. ischnus* is present mainly on stone or gravel substrates along the shallow margins of lakes and large rivers (Nesemann *et al.* 1995, Van Der Velde *et al.* 1999), and greatest densities are often found in shallow water (< 2 m) within *Dreissena* clusters (Kohn and Waterstraat 1990). In the Great Lakes, this species has been found in similar habitats, being most abundant around concrete slabs, cobble, and within *Dreissena* colonies in shallow water (< 3 m) in the Detroit River, Lake Erie, and Lake Ontario (Witt *et al.* 1997, Dermott *et al.* 1998, Stewart *et al.* 1998). Bially and MacIsaac (2000) found *E. ischnus* in shallow, soft-substrate locations in Lake Erie, but only in close association with *Dreissena* clusters. The finding in this study of *E. ischnus* unassociated with *Dreissena* in a deep-water, soft-bottom habitat is unusual, and certainly a new habitat for this species in the Great Lakes. However, *E. ischnus* has been found at depths to 300 m on mud substrates in the Caspian Sea (Birshtein and Romanova 1968, Kasymov 1994). The rapid spread of *E. ischnus* through the canal systems in Europe (Jazdzewski 1980), and its spread from the west end of Lake Erie to the east end in just two years (Dermott *et al.* 1998) would suggest that this species is very active in the water column. Vertical migrations into the water column have been documented (Dediu 1980), and a few *E. ischnus* have been collected in vertical net tows taken at night at 45-m depth off Muskegon (S. Pothoven, unpublished data). Pelagic individuals in shallow

TABLE 3. Mean (± SE) density (per m^2) of* Dreissena polymorpha *in each of four depth categories in the southern basin of Lake Michigan in 1992, 1993, 1998, and 1999. Given in parentheses is the number of sites where* D. polymorpha *was present relative to the number of sites sampled in each depth category.* D. bugensis *was not collected at any of the sites.

Depth Interval (m)	Number of Stations	Year			
		1992	1993	1998	1999
≤ 30	11	389 ± 253 (11)	1,929 ± 1,698 (11)	978 ± 255 (11)	2,056 ± 1,014 (11)
31–50	12[a], 23[b]	7 ± 3 (5)	25 ± 12 (10)	433 ± 156 (19)	1,059 ± 414 (21)
51-90	11[a], 15[b]	1 ± 1 (1)	1 ± 1 (3)	5 ± 3 (6)	3 ± 2 (5)
> 90	6	0 ± 0 (0)	0 ± 0 (0)	4 ± 4 (1)	0 ± 0 (0)

[a] Number of stations sampled in 1992 and 1993
[b] Number of stations sampled in 1998 and 1999

water can be swept to deeper regions by nearshore-offshore bottom currents that can occur in the southern basin (Meyers and Eadie 1993). The finding of six individuals in one replicate at the 45-m site off St. Joseph would suggest that *E. ischnus* is capable of colonizing substrates in deeper regions—transient individuals occurring in the water column and trapped incidentally in the grab sampler during its descent would probably not have shown such a clumped distribution.

The high number of *E. ischnus* within a clump of *D. polymorpha* at the 16-m site seems to confirm the close association between these two species. At this site, *E. ischnus* was found only in the replicate with the largest number of mussels, even though at least some mussels were present in the other two replicates. *E. ischnus* likely utilizes mussel biodeposits as a food source, but the close association between the species is more likely a result of a preference by *E. ischnus* for the greater habitat complexity within mussel colonies (van Overdijk 2000).

E. ischnus was the only amphipod collected in the rocky habitats sampled along the entire eastern shoreline of the lake. Although information on the amphipod taxa present in these areas prior to the sampling conducted in this study is lacking, *Gammarus* is a common component of the fauna found within rocky, breakwall habitats in the Great Lakes (Manny *et al.* 1985), and *Hyallela* is commonly found in cobble areas nearshore (Winnell and Jude 1987). Thus, the absence of both these species in the net samples along the eastern shoreline appears to be consistent with the finding that *E. ischnus* competitively displaces other amphipod taxa in rocky habitats (Dermott *et al.* 1998). Both *Gammarus* and *Hyallela*, but not *E. ischnus*, were found at shallow water sites in the Straits. Substrates at these sites were variable and consisted of medium to coarse sand (gravel), silt, and submerged vegetation. Such substrates may be more favorable to *Gammarus* and *Hyallela* than to *E. ischnus* as suggested by Dermott *et al.* (1998). The alternative is that *E. ischnus* has not yet colonized these substrates in the northern portion of the lake. Studies have shown that *E. ischnus* is frequently found on silty sand, sand, and within filamentous algae including *Cladophera* (Dediu 1967, 1980; van Overdijk 2000).

It remains questionable whether *E.ischnus* will become abundant in the offshore region of Lake Michigan (> 30 m). This species has a preference for hard substrates over soft (Birshtein and Romanova 1968), and the latter type is dominant in offshore regions. Yet, given the close association between *E. ischnus* and *Dreissena*, the expansion of *Dreissena* at depths below 30 m may increase the possibility of significant *E. ischnus* populations in deepwater. Presently, *D. polymorpha* populations in Lake Michigan are expanding most rapidly at depths between 30 and 50 m, but are generally not abundant at depths > 50 m (Table 3; Fleischer *et al.* 2001). On the other hand, *D. bugensis* will likely occur at depths > 50 m, and replace *D. polymorpha* at the 30 to 50 m interval as found in Lake Ontario (Mills *et al.* 1999).

The expansion of *E. ischnus* and *D. bugensis* over wide areas will likely have implications to the Lake Michigan food web. For one, *E. ischnus* may become a food item for many fish species. It has been intentionally introduced into some Russian water bodies, presumably as a diet item for forage fish (Olenin and Leppakoski 1999), and it has been found in the stomachs of yellow perch and whitefish collected at a depth of 20 m in Lake Michigan (S. Pothoven, unpublished data). Besides a potential role in expanding the depth range of *E. ischnus*, *D. bugensis* will likely cause other changes to the offshore food web. The benthic amphipod *Diporei*a is declining in the lake, likely as a result of food depletion from the filtering activities of *D. polymorpha*, or some other *Dreissena*-related factor (Nalepa *et al.* 1998, 2000). With *D. bugensis* now present and poised to expand in the offshore region, the rate of decline in *Diporeia* will likely increase, and the lake area devoid of this important fish-food organism will become more extensive. To be certain, the offshore benthic community in Lake Michigan will continue to change, and questions such as whether *E. ischnus* will play an expanded role in the food web in areas where *Diporeia* is no longer found can only be answered with further studies.

ACKNOWLEDGMENTS

We thank Glenn Carter, Pat Charlebois, and David Jude for help in the collection of samples; the crews of the R/V *Shenehon* and *Lake Guardian* for assistance during field operations; Gregory Lang for constructing Figure 1; Cathy Darnell for editorial assistance; Jonathan Witt for confirming the identification of specimens from the deepwater habitats; and C. van Overdijk and I. Grigorovich for helpful comments on the manuscript. I. Grigorovich also provided translated information from the Russian literature that was extremely valuable. This arti-

cle is GLERL Contribution # 1202 and Contribution # 1143 of the USGS Great Lakes Science Center.

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Submitted: 15 November 2000
Accepted: 3 April 2001
Editorial handling: Trefor Reynoldson