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1 Bad taxonomy can kill: Molecular re-evaluation of *Unio mancus* Lamarck, 1819  
2 (Bivalvia: Unionidae) and its accepted subspecies

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21 systematics, species delimitation.

22

23 Abstract

24 The conservation status of European unionid species rests on the scientific  
25 knowledge of the 1980s, before the current revival of taxonomic reappraisals  
26 based on molecular characters. The taxonomic status of *Unio mancus* Lamarck,  
27 1819, superficially similar to *Unio pictorum* (Linnaeus, 1758) and often  
28 synonymized with it, is re-evaluated based on a random sample of major French  
29 drainages and a systematic sample of historical type localities. We confirm the  
30 validity of *U. mancus* as a distinct species occurring in France and Spain, where it  
31 is structured into three geographical units here ranked as subspecies: *U. m.*  
32 *mancus* [Atlantic drainages, eastern Pyrenees, Spanish Mediterranean drainages],  
33 *U. m. turtonii* Payraudeau, 1826 [coastal drainages East of the Rhône and Corsica]  
34 and *U. m. requienii* Dupuy, 1843 [Seine, Saône-Rhône, and coastal drainages  
35 West of the Rhône]. Many populations of *Unio mancus* have been extirpated  
36 during the 20th century and the remaining populations continue to be under  
37 pressure; *U. mancus* satisfies the criteria to be listed as "Endangered" in the IUCN  
38 Red List.

39

40 Les risques d'une mauvaise taxonomie : ré-évaluation moléculaire d'*Unio mancus*  
41 Lamarck, 1819 (Bivalvia : Unionidae) et de ses sous-espèces.

42

43 Résumé

44 Le statut de conservation des espèces d'unionidés européennes repose sur les  
45 connaissances scientifiques des années 1980, avant le renouveau des ré-  
46 évaluations taxonomiques basées sur des caractères moléculaires. Le statut  
47 taxonomique de la Mulette méridionale *Unio mancus* Lamarck, 1819,  
48 superficiellement semblable à la Mulette des peintres *Unio pictorum* (Linnaeus,  
49 1758) et souvent mise en synonymie avec elle, est ici ré-évalué sur la base d'un  
50 échantillonnage à l'aveugle des grands bassins versants français et d'un  
51 échantillonnage ciblé des localités-types historiques. Nous confirmons la validité  
52 d'*Unio mancus* comme espèce distincte, présente en France et en Espagne, où elle  
53 est structurée en trois unités géographiques ici traitées comme sous-espèces : *U.*  
54 *m. mancus* [bassins versants atlantiques, est des Pyrénées, bassins versants  
55 méditerranéens espagnols] *U. m. turtonii* Payraudeau, 1826 [bassins versants des  
56 fleuves côtiers à l'est du Rhône et de Corse] et *U. m. requienii* Dupuy, 1843  
57 [Seine, Saône-Rhône, et fleuves côtiers à l'est du Rhône]. De nombreuses  
58 populations d'*Unio mancus* ont été éradiquées dans le courant du 20ème siècle et  
59 beaucoup de populations restantes restent menacées ; l'espèce répond aux critères  
60 "En Danger" pour la Liste Rouge de l'UICN.

61

62 Introduction

63 Freshwater mussels combine several life history traits (longevity, filter feeding,  
64 larvae parasitic on the gills of fishes) that make them particularly vulnerable to  
65 loss of habitat quality. Unionidae have the dubious privilege of being among the  
66 most threatened freshwater invertebrates (Lydeard *et al.* 2004), with 20% of North  
67 American species already listed as Extinct or Possibly Extinct (Master *et al.*  
68 2000), and a number of European species protected under national or European  
69 regulations. Because legislative texts protect species through names, it is  
70 important that names reflect appropriate evolutionary and/or conservation units.  
71 However, the taxonomy of European unionids is still unstabilized, especially in  
72 southern Europe, and the current listings on legislative texts - which reflect the  
73 scientific knowledge of the 1980s - have not kept pace with advances in  
74 taxonomical knowledge.

75 The taxonomy of European unionids is plagued with a plethora of names. Based  
76 on a typological approach to within- and between-population phenotypic  
77 diversity, hundreds of nominal species have been described, especially as a result  
78 of the excesses of the 19th century French “Nouvelle École” (see Bouchet 2002).  
79 There is an important body of classical and modern literature that documents shell  
80 plasticity in unionoids (e.g., Ortmann 1920; Agrell 1948; Nagel 1992; McMurray  
81 *et al.* 1999; Watters 1994; Zieritz and Aldridge 2009; Zieritz *et al.* 2010) and,  
82 based on phenotypic resemblances, these 19th century names have ended up in  
83 synonymy (see, among others, Haas 1969). Molecular techniques are now  
84 allowing a fresh evaluation of these nominal species, confirming in many cases

85 morphology-based synonymies (Araujo *et al.* 2005; Araujo *et al.* 2009b), but  
86 sometimes leading to the revalidation of some abusively synonymized species  
87 (Araujo *et al.* 2009a, Araujo *et al.* 2009b; Reis and Araujo 2009; Khalloufi *et al.*  
88 2011). Conservation programs now largely advocate the use of genetic approaches  
89 to evaluate the validity of the evolutionary and/or conservation units being  
90 managed (Schonewald-Cox *et al.* 1983; Machordom *et al.* 2003; Geist and Kuehn  
91 2005).

92 "Bad taxonomy can kill" (May 1990, Mace 2004). Given the subjective basis of  
93 the taxonomic validity of many nominal species, it is not impossible that  
94 important conservation units remain unrecognized or buried in the "graveyard of  
95 synonymy". Clarifying the taxonomic status of potentially endangered taxa is thus  
96 a major concern. Among the unionoids of French hydrographic basins, the  
97 taxonomic status of *Unio mancus* Lamarck, 1819 has been controversial in the  
98 recent literature. Based on shell characters, Haas (1969) considered *U. mancus* as  
99 one of the subspecies of *U. elongatulus* C. Pfeiffer, 1825 (despite the  
100 nomenclatural priority of *mancus* over *elongatulus*). Nagel and Badino (2001),  
101 based on enzymatic studies, treated *U. mancus* as a subspecies of *U. pictorum*  
102 (Linnaeus 1758). In the taxonomic authority list of French non-marine molluscs,  
103 Falkner *et al.* (2002) listed *U. mancus* as a valid species with seven subspecies,  
104 largely inspired from Haas' (1969) subspecies of *U. elongatulus*: *U. m. mancus*  
105 [Seine, Loire, Charente basins, coastal rivers of Normandy], *U. m. aleronii*  
106 Companyo and Massot, 1845 [eastern Pyrenees and Garonne basin], *U. m.*  
107 *bourgeticus* Bourguignat in Locard, 1882 [Saône and Ain drainages, Lake

108 Bourget], *U. m. brindosianus* de Folin and Berillon, 1874 [coastal lakes of the  
109 Landes], *U. m. moquinianus* Dupuy, 1843 [piedmont of central and western  
110 Pyrenees], *U. m. requienii* Michaud, 1831 [Rhône basin downstream of Lyon],  
111 and *U. m. turtonii* Payraudeau, 1826 [Corsica], suggesting that their geographical  
112 segregation implied underlying genetic isolation. The status of *U. mancus* as a  
113 valid species was confirmed by Araujo *et al.* (2005) based on molecular and  
114 ecological data on Spanish populations. Except for *U. aleronii* (synonymized with  
115 *U. mancus* by Araujo *et al.* 2009c), the status of the subspecies recognized by  
116 Falkner *et al.* (2002) has not been further evaluated.

117 Because of the considerable phenotypic variation of the shell in unionids, the  
118 application of names beyond their type locality or, at least, beyond the  
119 hydrographic basin of their type locality, is problematic. In consequence, and  
120 through COI sequences obtained from topotypical populations, the purpose of the  
121 present study is (1) to re-evaluate the taxonomic status of *Unio mancus* and  
122 compare it specifically with *U. pictorum*, and (2) to evaluate the taxonomic status  
123 of the different nominal subspecies of *U. mancus*.

124

125 Material and methods

126 Material studied

127 The main drainage systems of France (Rhine River excepted) were sampled, with  
128 special consideration for the type localities of the accepted subspecies (Figure 1,  
129 Table I). Sampling was successful for type localities of *Unio m. mancus* Lamarck,  
130 1819, *Unio m. aleronii* Companyo and Massot, 1845, *U. m. bourgeticus*  
131 Bourguignat, 1882, *U. m. brindosianus* de Folin and Bérillon, 1874, *U. m.*  
132 *requienii* Michaud, 1831 and *U. m. turtonii* Payraudeau, 1826. *U. m. moquinianus*  
133 Dupuy, 1843, seems to have been extirpated from its type locality and we sampled  
134 nearby localities belonging to the same drainage. In addition, specimens from  
135 Lake Maggiore in Italy were included in the dataset. A total of 151 specimens  
136 were sampled in 38 localities (Figure 1, Table I).

137 DNA analysis

138 A piece of foot was clipped from living specimens and preserved in 90% ethanol.  
139 Soft tissues and shells are kept in the Muséum national d'Histoire naturelle in  
140 Paris (see Table I for voucher numbers). DNA was extracted from these samples  
141 using the Nucleospin Tissue Kit (marketed by Macherey Nagel), following the  
142 manufacturer's protocol. A fragment of the cytochrome oxidase subunit I (COI)  
143 gene was amplified by PCR using the universal primers LCO1490 and HCO2198  
144 (Folmer *et al.* 1994) or our own designated primers (CO1UnioF:  
145 TGTTAGCTTTGTGATCTGGGTTAATTGG; CO1UnioR:  
146 AAATTGGATCACCTCCCCAGTAGGG). The PCR mix contained 20 ng of  
147 DNA, 1U of Fast Start Taq (commercialized by Roche), 6 pmol of dNTP mix,



148 37.5 pmol of MgCl<sub>2</sub>, 1 pmol of each primer and H<sub>2</sub>O was added for a final volume  
149 of 50 µl. PCR started with an initial denaturation cycle at 95 °C for 10 min,  
150 followed by 50 cycles of 95 °C for 30 s, 60 °C for 30 s, 72 °C for 1 min, and a  
151 final extension at 72 °C for 10 min. The PCR products were purified using  
152 Nucleofast Plates (commercialized by Macherey Nagel) and sequenced in a  
153 3730XL genetic analyser (Applied Biosystems). Extractions, amplification and  
154 sequencing were performed by Genoscreen (France) and Eurofins (Germany).  
155 Fifteen sequences from Araujo *et al.* (2005) (for *U. mancus*) and from Soroka  
156 (2010) (for *U. pictorum*) were downloaded from GenBank and included in the  
157 analyses (see Table I for GenBank accession numbers). These were selected  
158 because the sequences are linked to voucher specimens.  
159 The 154 sequences obtained in this study and the 15 sequences downloaded from  
160 GenBank were aligned using ClustalW multiple alignment implemented in Bio-  
161 Edit (Hall, 1999). MEGA 5 (Tamura *et al.* 2011) was used to calculate the p  
162 distances between each pair of specimen. The GTR + I + G model was identified  
163 as the best-fitting substitution model by JModeltest 0.1.1 (Posada, 2008)  
164 following the Akaike criterion. This model has been used for the Bayesian  
165 analysis, performed running two parallel analyses in MrBayes (Huelsenbeck *et al.*  
166 2001), consisting each of two Markov chains of 15,000,000 generations each,  
167 sampled every 5,000 generations. A consensus tree was then calculated after  
168 omitting the first 25% trees as burn-in.  
169 The Bayesian analyses were run on the 26 different haplotypes obtained from the  
170 169 sequences involved in this study. *Unio tumidus* Philipsson, 1788 and *Unio*

171 *crassus* Philipsson, 1788 were chosen as outgroups, as they are considered to be  
172 closely related to *U. mancus* and *U. pictorum* (Nagel and Badino 2001).  
173 *Margaritifera auricularia* (Spengler, 1793) was chosen as distant outgroup to  
174 assess the monophyly of *U. mancus* and *U. pictorum*.  
175

176 Results

177 On the phylogenetic tree (Figure 2), three main clades were defined. Sequences  
178 from GenBank identified as *Unio mancus* by Araujo *et al.* (2005) clustered in  
179 clade 1 together with our own material of *U. mancus* and its subspecies.  
180 Specimens from the Italian lake cluster in clade 2. Sequences of specimens  
181 identified as *U. pictorum* by Soroka (2010) all clustered in clade 3 together with  
182 our own material of *U. pictorum*. Average divergence within the *U. pictorum*  
183 clade was 0.3 % (max: 1 %), average divergence within the *U. mancus* clade was  
184 0.5 % (max 1.3 %), minimum distance between *U. mancus* and *U. pictorum* was  
185 2.9 %. *U. mancus* and *U. pictorum* were found monophyletic.

186 *U. pictorum* has been found mainly in northern France (Seine and Meuse basins),  
187 with isolated populations in Lake Bourget, Lake Brindos and the Garonne basin,  
188 suggesting a broader distribution but scattered occurrences (Figure 3, Table I). *U.*  
189 *mancus* is found in the Mediterranean drainages of France and eastern Spain to  
190 the Seine basin in the north. Beyond this presumably natural distribution, *Unio*  
191 *mancus* occurs in the Rhine, and Glöer and Zettler (2005) have suggested that this  
192 is the result of an expansion through the Rhine-Rhône canal (established in 1833),  
193 where it was not reported before 1911 (as *Unio voltzii* Kobelt, 1911; see Haas  
194 1969). *U. mancus* has not been found in the Meuse River.

195 Specimens from Lake Maggiore in Italy have been referred to “*U. pictorum*  
196 *mancus*” by Ravera *et al.* (2007), while Gavetti *et al.* (2008) identify them as *U.*  
197 *mancus*. The specimens from Lake Maggiore form a distinct lineage from *U.*

198 *mancus* (Figure 2, clade 2), which is identifiable as *Unio elongatulus*, after Bodon  
199 *et al.* (1995) and the Italian fauna Checklist ([www.faunaitalia.it](http://www.faunaitalia.it)).

200 Within the *U. mancus* clade, populations were divided in three geographic groups  
201 (Figure 3): Group 1a included the populations from Atlantic drainages (Loire,  
202 Garonne), plus the Mediterranean populations from Spain and from the Basse  
203 River near Perpignan (posterior probabilities = 1); group 1b included the  
204 populations from Corsica and South-East France, i.e. drainage systems East of the  
205 Rhône (posterior probabilities = 0.86); group 1c the populations from the Rhône,  
206 Hérault and Seine drainages (posterior probabilities = 0.45). These three  
207 evolutionary units are characterized by several diagnostic characters: clade 1a  
208 differs from all other by three fixed apomorphies (bp 448: T instead of C; bp 478:  
209 A instead of G; bp 518: G instead of A), clade 1b by one apomorphic character  
210 (bp 169: A instead of G) and clade 1c by one apomorphy (bp 346: G instead of  
211 A). On the three specimens from Lake Bourget attributable to *U. mancus*, one  
212 constitutes a distinct haplotype with only one different character (bp 455: G  
213 instead of T). *U. m. turtonii* is not distinct from continental populations of South-  
214 East France (Argens). *U. m. moquinianus* and *U. m. aleronii* cluster in the same  
215 group as the nominate *U. m. mancus* (Loire), and their haplotypes are shared by  
216 most of the specimens sampled (none of them constitute a distinct clade).  
217 Specimens from the type locality of *U. m. brindosianus* were found to belong to  
218 the *U. pictorum* clade, as well as two specimens from Lake Bourget that did not  
219 differ in shell shape from *U. mancus* from the same locality (Figure 4I-J).

220

221 Discussion

222 Validity of *Unio mancus*

223 Haas (1969) suspected the possible existence of hybrids between *U. mancus* and  
224 *U. pictorum* in the Seine and Marne Rivers. Nagel and Badino (2001) considered  
225 them conspecific. Our results support the distinction between *U. mancus* and *U.*  
226 *pictorum*, the former currently present in the Atlantic drainages from the Pyrenees  
227 to the small drainages of Brittany, in the Seine basin in upstream Aisne and Marne  
228 Rivers, and in Mediterranean drainages, Corsica included. Furthermore, these  
229 populations are conspecific with *U. mancus* as identified by Araujo *et al.* (2005)  
230 in Spain. The species level status of *mancus* is further supported by the syntopic  
231 co-occurrence of *U. mancus* and *U. pictorum* in Lake Bourget and in the Cher,  
232 Ourcq, Seine and Aisne Rivers (Figure 3, Table I).

233 Within *Unio mancus*, the French populations cluster in three COI sequences  
234 groups (1a, 1b and 1c) that do not correspond to the subspecies delimitations  
235 proposed by Haas (1969) and retained by Falkner *et al.* (2002). However,  
236 although sampling topotypes is in principle the most reliable approach to evaluate  
237 the status of a nominal (sub)species, it is not certain that material collected in  
238 2010-2011 belongs to the same gene pool as the specimens occupying the type  
239 localities in the mid-19th century, when the nominal species were described.  
240 Aquatic ecosystems have been strongly impacted by human activities over the last  
241 century. Water quality has been globally declining, sediment quality has been  
242 modified by dams and channelization (Sabater 2008, Sabater and Tockner 2009),  
243 and these changes may have locally led to extirpation of populations. Previously

244 isolated drainage systems are now connected by canals and through fish  
245 translocation, which induce translocation of associated bivalves through the larval  
246 parasitic stage (Nagel 2000; Gherardi *et al.* 2008; Cappelletti *et al.* 2009),  
247 resulting in new gene pools being introduced to old localities. Because of the  
248 potential colonization and introgression, the geographical genetic structuring  
249 observed in the 21st century may thus be different from that in the 19th century  
250 when names were established. Sampling of specimens at the type locality is thus  
251 not sufficient to guarantee that the specimens are genuinely representative of  
252 nominal (sub)species originally described from that locality. To avoid a wrong  
253 application of the name to supposedly topotypical specimens, it is thus essential to  
254 compare them morphologically to the historical type specimens (when available).  
255 With this caveat in mind, it is not entirely certain that present-day populations in  
256 Lake Bourget (type locality of *U. m. bourgeticus*) represent the same gene pool as  
257 in the 1880s. The specimens sampled (Figure 4G-J) have uniformly small,  
258 brownish and rounded shells that do seem similar to the type specimens (MNHN  
259 22139, Figure 4K), but the latter are more kidney-shaped. Furthermore, whereas  
260 based on COI sequences evidence both *U. pictorum* and *U. mancus* are now  
261 present in the lake, we found no morphological differences between them. If this  
262 situation existed already in the 19th century, then the allocation of the type  
263 material of *Unio bourgeticus* to either *U. mancus* or *U. pictorum* is problematical.  
264 Likewise, the specimens sampled in Lake Brindos (type locality of *U. m.*  
265 *brindosianus*) were all attributable to *U. pictorum* according to COI sequences,  
266 but it is not clear whether they correspond genuinely to what was historically

267 described as *U. brindosianus* (which would then be a synonym of *U. pictorum*), or  
268 whether *U. mancus* has been extirpated from that locality and replaced by the  
269 ecologically more tolerant *U. pictorum*.

#### 270 Evaluation of the morphological variability

271 Important morphological variations exist in shell size, shape and colour of *U.*  
272 *mancus* (Figure 4, more material is illustrated in Prié 2012).

273 Specimens from the Loire (Figure 4B) and Seine drainages (Figure 4C), including  
274 the nomenclatural lectotype designed by Falkner (1994) (Figure 4A), have small-  
275 sized, elongated, and rather yellowish shells; by contrast, specimens from Brittany  
276 have larger and much darker shells (Figure 4D). The population from the Basse  
277 River (type locality of *U. m. aleronii*, Figure 4E) is characterized by small, ovate,  
278 rather greenish shells. Their COI sequences are similar to those from Atlantic  
279 drainages and to the morphologically very different specimens from Spain  
280 (Araujo *et al.* 2005; Araujo *et al.* 2009c). The sampled population from the Adour  
281 drainage (Pyrenees) has small and rounded shells (Figure 4F), with a very dark  
282 color, that corresponds to the original description of *U. m. moquinianus* and its  
283 taxonomical extension in Haas (1969). Their COI sequences belong to the same  
284 clade as populations from the Loire and Charente Rivers, which have very  
285 different shell shape and color.

286 Specimens from Lake Bourget (Figure 4G-J) are morphologically homogeneous,  
287 with shells resembling those from the Aisne River, but their COI sequences  
288 correspond to two species, *U. pictorum* and *U. mancus*. However, none of the

289 specimens sampled matches perfectly the kidney-shape and dark shells of 19<sup>th</sup>  
290 century historical type specimens (Figure 4K).

291 Populations from Corsican and Mediterranean drainages have large, often kidney-  
292 shaped shells with a brownish colour (Figure 4L-O). They belong to two distinct  
293 clades, one of them, despite different shell shapes, including the Lake Bourget and  
294 Seine basin populations. Material from Corsica matches the original description of  
295 *U. m. turtonii*, but this description is vague enough to correspond to any *U.*  
296 *mancus* population from southern France. Characters such as the thickness of the  
297 shells are most probably linked to water quality: Corsican populations of *U.*  
298 *mancus* live on an acid substrate whereas the mainland populations sampled live  
299 mainly on limestone.

300 Incongruence of morphology with DNA sequences data has been noted in  
301 previous studies (Nagel 1992; McMurray *et al.* 1999; Zieritz *et al.* 2010). Because  
302 the historically restricted-range *U. m. aleronii*, *U. m. bourgeticus* and *U. m.*  
303 *moquinianus* cannot be separated by COI sequences, there is no support to regard  
304 them as separate taxa despite their morphological singularities.

#### 305 Structuring within *U. mancus*

306 Despite the weak posterior probabilities, the genetic structure within *U. mancus* is  
307 biogeographically cohesive and coherent, supporting the recognition of three  
308 different evolutionary/conservation units corresponding to the three groups 1a, 1b  
309 and 1c (Figure 3).

310 Group 1a includes the populations from Atlantic drainages, from the Pyrenees to  
311 Brittany, including the Loire basin, as well as the population from the Basse River



312 in Perpignan. Outside France, it includes Spanish Mediterranean drainages as far  
313 South as the Jucar River basin. This clade corresponds to the subspecies *Unio m.*  
314 *mancus*, *Unio m. aleronii*, *U. m. moquinianus* as recognized by Falkner *et al.*  
315 (2002), and should thus be known as the nominotypical subspecies *Unio m.*  
316 *mancus*, with the other names as synonyms. The genetic similarity between  
317 populations from the Loire and the Adour-Garonne systems was not expected as  
318 the Adour and Garonne drainages have to this day remained unconnected by  
319 canals (Persat and Keith 2011). This distribution matches that of *Leusiscus*  
320 *burdigalensis* Valenciennes, 1844 (with the taxonomic extension of Keith *et al.*,  
321 2011). Interestingly, the genus *Leusiscus* Cuvier, 1816 is closely related to  
322 *Squalius* Bonaparte, 1837, which includes two species known as efficient host  
323 fishes for *U. mancus* (Araujo 2005), suggesting that *L. burdigalensis* should be  
324 tested as a larval host for *Unio mancus*. The co-clustering of populations from  
325 Spanish Mediterranean drainages and French Atlantic drainages evidences that,  
326 counter-intuitively, the Pyrenees are not a significant biogeographic barrier.  
327 Interestingly, fishes like the Iberian gudgeon *Gobio lozanoi* Doadrio and Madeira,  
328 2004 or the Adour minnow *Phoxinus bigerri* Kottelat, 2007 are also distributed in  
329 both the Ebro basin in Spain and the Adour basin in the French Atlantic drainage  
330 (Kottelat and Freyhof 2007, Keith *et al.* 2001). The distribution of *Squalius*  
331 *laietanus* Doadrio, Kottelat and de Sostoa, 2007, including the Ebro basin and the  
332 southernmost French Mediterranean Rivers (Kottelat and Freyhof 2007, Keith *et*  
333 *al.* 2001), parallels that of clade 1a in the Basse River. Such distributions may

334 have their origin in the connections between French and Spanish hydrographic  
335 systems during periods of low sea levels (Persat and Keith, 2011).

336 The Rhône, Vidourle and Hérault rivers have been connected in the past when the  
337 sea level was lower, which can explain the similarity of fauna in the rivers  
338 draining to the Golfe du Lion (Persat and Keith, 2011). This is congruent with the  
339 COI sequences results in our analysis. By contrast, an unexpected result of our  
340 study was the allocation of specimens from the Seine drainage system to clade 1c.  
341 This was unexpected as the fauna of the Seine is in general more similar to that of  
342 the Loire due to (i) connections during geological time until the early Pleistocene,  
343 and (ii) historically (year 1642), the opening of the canal de Briare connecting the  
344 Loire and the Loing (a tributary of the Seine). The artificial connection between  
345 the Rhône and the Seine systems was established later in 1832 (through Canal de  
346 Bourgogne between Ouch and Armacon Rivers) and 1907 (canal between the  
347 Saone and Marne Rivers). We hypothesize that the occurrence of *U. mancus* in  
348 the Seine is the result of a modern colonization event, either *via* canals or fish  
349 translocation.

350 Falkner *et al.* (2002) restricted the name *U. m. turtonii* to Corsican populations  
351 and questioned the identity of populations for continental rivers East of the  
352 Rhône. The clustering of COI sequences of specimens from South-East France  
353 and Corsica in group 1b is congruent with Germain's (1931) opinion, and the  
354 name *U. m. turtonii* is applicable to it.

355 Clade 1c corresponds to the subspecies *U. m. requienii* as recognized by Falkner  
356 *et al.* (2002), but with a distribution here extended to the Hérault River and to the

357 Seine system. (The identity of *U. m. bourgeticus*, from the Rhône drainage,  
358 remains in doubt as collected material seems different from type material, but it is  
359 probably a synonym of *U. m. requienii*).

#### 360 Conservation issues

361 When the appendices to the Habitats and Species Directive (92/43/EEC) were put  
362 together back in the early 1990s (see Bouchet *et al.* 1999 for a history of how the  
363 list was compiled), the prevailing scientific opinion was that *Unio pictorum* was a  
364 polytypic species, with a broad range extending from Portugal to Estonia, and was  
365 not endangered. The then poorly known *U. mancus* was not explicitly considered,  
366 and was probably implicitly considered to be part of the variation of *U. pictorum*  
367 (e. g. in the Habitats Directive) or *U. elongatulus* (e. g. in the Bern Convention).  
368 The recognition of *U. mancus* as a distinct species, endemic to a few drainages in  
369 France and Spain, has of course radical consequences in a conservation  
370 perspective (Morrison *et al.* 2009).

371 Extensive sampling in the main drainages in the course of the present study  
372 resulted in the discovery of healthy populations of *Unio mancus*, particularly in  
373 Atlantic drainages, as well as healthy populations of *U. crassus*, a species  
374 considered endangered, protected in France and listed in the Habitats Directive.  
375 However, compared to *U. crassus*, *U. mancus* has a much more restricted range,  
376 with drainages in Mediterranean and southwestern France contributing most  
377 populations. These drainages are heavily impacted by human activities and  
378 systematic sampling of historical localities indicates an important decline of  
379 populations, giving cause of concern for their conservation status.

380 Intensive farming produces considerable pollutants effluents: 73,000 tons of  
381 phytosanitary products have been used in France in 2004, and pesticides have  
382 been detected in 96% of French rivers checkpoints (IFEN 2006). Dams and  
383 impoundments for irrigation are a primary cause of fragmentation and habitat loss  
384 due to siltation (Strayer 2006, Sabater 2008); water extraction and severe droughts  
385 heighten the concentration of pollutants and eutrophication effects (Sabater and  
386 Tockner 2009). It thus does not come as a surprise that the distributions and  
387 abundances of unionids in French rivers differ – sometimes considerably – from  
388 what can be inferred from 19<sup>th</sup> century publications. For instance, the type  
389 localities of *U. m. moquinianus* do not seem to host *Unio* species any more: the  
390 Echez and Arros Rivers are both highly impacted by intensive corn farming. Only  
391 a few live specimens were found in the Drée River (type locality of *U. m.*  
392 *mancus*), whereas numerous recently dead specimens covered the river bed,  
393 indicating a recent die-off. The Drée River is subject to recurrent pollution from  
394 malfunctioning sewage treatment plants, and an important pollution, involving  
395 fish mortality, occurred in summer 2010 during a low water event. Although we  
396 could find living *Unio* in Lake Brindos, these were very scarce and no juveniles  
397 were encountered, indicating a declining population. Indeed, the site is affected by  
398 heavy organic siltation, the substrate is dominated by anoxic sludge, and the  
399 survival of this population is obviously compromised. As noticed above,  
400 specimens collected in Lake Le Bourget differ morphologically from specimens  
401 historically collected in that lake, and a doubt remains concerning the survival of  
402 such historical *U. m. bourgeticus* morphotypes.

403 Populations in the Mediterranean drainages have become very restricted and  
404 demographically weak. Mediterranean rivers are affected by water restriction,  
405 which increases the effect of other stressors such as pollutants, UV-impact and  
406 thermal stress (Tockner *et al.* 2010), and should be even more impacted by human  
407 activities and global changes in the future (Alcamo *et al.* 2007; Sabater and  
408 Tockner 2009). French Mediterranean drainages are home to two subspecies, for  
409 which conservation efforts should be considered. In Corsica, *U. m. turtonii* was  
410 historically known from at least eight rivers (Payraudeau 1826), which have all  
411 been resurveyed (this paper and Araujo, pers. com.); *Unio m. turtonii* has likely  
412 been extirpated from three of these sites. It also seems to have recently been  
413 locally extirpated from the River Argens by a major flood that occurred in  
414 December 2010 after our sampling had taken place. The type locality of *U. m.*  
415 *aleronii* in the Basse River is now restricted to a stretch of a few hundreds of  
416 meters, between the suburbs of Perpignan downstream and the newly built railway  
417 line upstream.

418 Robust taxon delimitation of, and within, *U. mancus* thus suggests its  
419 conservation status should be revised to take into account the impact of habitat  
420 degradation on the size and number of populations of its constituent subspecies or  
421 evolutionary units.

#### 422 IUCN categorization

423 *U. mancus* is currently considered “Near Threatened” on the IUCN European Red  
424 List of Non-Marine Molluscs (Cuttelod *et al.* 2011). At the time when the Red  
425 List was compiled (2009), criterion A (declining population) was not used as no

426 precise data were available to support it. This is the unfortunate fate of  
427 invertebrate taxa: despite evidence of an alarming global decline of non-marine  
428 molluscs (Lydeard *et al* 2004), we generally lack proper data to assess population  
429 decline for each taxon considered. In this paper, 18 historical localities have been  
430 re-sampled. Despite an intensive search involving several prospectors and  
431 appropriate approaches (aquascope, dredging, scuba diving), the result was that 10  
432 of these 18 populations have been extirpated since the early 1900s and four out of  
433 the remaining eight are declining. Moreover, global decline can be inferred from  
434 the well documented decline of habitat and water quality. It is therefore likely that  
435 population reduction has reached over 50% during the 20<sup>th</sup> century. The causes  
436 are not clearly understood, they have not ceased and are in most cases not  
437 reversible; inferred decline is based on direct observation, decline in Area Of  
438 Occurrence (AOO), and effect of pollutants. Based on these considerations, *U.*  
439 *mancus* meets the criteria A2ace to categorize as "Endangered".

440 With regard to criteria B (restricted range and fragmentation, decline or  
441 fluctuations) and C (small population size and decline or fluctuations), *U. mancus*  
442 has a relatively large distribution (about 800,000 km<sup>2</sup>, based on river basins) and  
443 healthy populations are known. Given this distribution and occurrence, criteria B  
444 and C are not globally applicable, but the present study stresses out the “severely  
445 fragmented” option in criterion B, which should be taken into account. Different  
446 COI lineages have been revealed in France but, although COI evolves at a fast  
447 rate, it is not enough to reveal population isolation nowadays. Therefore,  
448 fragmentation may be higher than suggested by COI sequences. Further studies on

449 population genetics may highlight distinct populations most likely isolated in  
450 independent hydrosystems.

451 Fragmentation and decline are an established fact, especially with regard to *U. m.*  
452 *turtonii* known only from six locations: one on the mainland (the population  
453 sampled by us has since been extirpated but specimens probably survive  
454 elsewhere in the River Argens), five in Corsica, with extirpation from three  
455 further localities within a century. However, total population probably exceeds  
456 10,000 individuals, and criterion C is not applicable. Criterion D (very small  
457 population or very restricted distribution) and E. (Quantitative analysis of  
458 extinction risk) are not applicable either.

459 Each of the three subspecies of *Unio mancus* recognized in the present study  
460 should arguably be considered as "Endangered". Despite a more restricted range  
461 and higher anthropogenic pressure on *U. m. turtonii*, it does meet the IUCN  
462 criteria for "Critically Endangered".

463

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475



476 References:

- 477 Agrell I., 1948. The shell morphology of some Swedish unionids as affected by  
478 ecological conditions. *Arkiv för zoologi*, 41A, 1-30.
- 479 Alcamo J., Flörke M. and Märker M., 2007. Future long-term changes in global  
480 water resources driven by socioeconomic and climatic change. *Hydrological  
481 Science Journal*, 52, 247-275.
- 482 Araujo R., Gomez I. and Machordom A., 2005. The identity and biology of *Unio*  
483 *mancus* Lamarck, 1819 (= *U. elongatulus*) (Bivalvia: Unionidae) in the Iberian  
484 Peninsula. *Journal of Molluscan Studies*, 71, 25-31.
- 485 Araujo R., Toledo C. and Machordom A., 2009a. Redescription of *Unio gibbus*  
486 Spengler, 1793, a west palaeartic freshwater mussel with hookless glochidia.  
487 *Malacologia*, 51, 131-141.
- 488 Araujo R., Toledo C., Van Damme D., Ghamizi M., and Machordom A., 2009b.  
489 *Margaritifera marocana* (Pallary, 1918): A valid species inhabiting Moroccan  
490 rivers. *Journal of Molluscan Studies*, 75, 95-101.
- 491 Araujo R., Reis J., Machordom A., Toledo C., Madeira M.J., Gómez I., Velasco J.  
492 C., Morales J., Barea J.M., Ondina P. and Ayala I., 2009c. Las náíades de la  
493 península ibérica. *Iberus*, 27, 7-72.
- 494 Bodon M., Favilli L., Giusti F. and Manganelli G., 1995. Gastropoda Pulmonata.  
495 *in*: Minelli A., Ruffo S. and La Posta S. [Eds]. Checklist delle specie della fauna  
496 italiana, Bologna (Calderini), 14, 1-160.
- 497 Bouchet P., 2002. Mollusques terrestres et aquatiques de France : un nouveau  
498 référentiel taxonomique, un nouveau départ, de nouvelles perspectives. *In*:

499 Falkner G., Ripken T. E. J. and Falkner M., 2002. Mollusques continentaux de  
500 France : Liste de Référence annotée et Bibliographie, *Patrimoines Naturels*, 52, 5-  
501 20.

502 Bouchet P., Falkner G. and Seddon M., 1999. Lists of protected land and  
503 freshwater molluscs in the Bern Convention and European Habitats Directive: are  
504 they relevant to conservation? *Biological Conservation*, 90, 21-31.

505 Cappelletti C., Cianfanelli S., Beltrami M. E. and Ciutti F., 2009. *Sinanodonta*  
506 *woodiana* (Lea, 1834) (Bivalvia: Unionidae): A new non-indigenous species in  
507 lake Garda (Italy). *Aquatic Invasions*, 4, 685-688.

508 Cuttelod A., Seddon M. and Neubert E., 2011. European Red List of Non-marine  
509 Molluscs. IUCN. Luxembourg, Publications Office of the European Union, 97 p.

510 Falkner G., 1994. Systematik vorderorientalischer Najaden als Vorstudie zur  
511 Bearbeitung archäologischer Funde. In: Kokabi M. and Wahl J. (Eds), Beiträge  
512 zur archäozoologie und prähistorischen Anthropologie, Forschungen und  
513 Bearbeitung archäologischer Funde. Forschungen und Berichte zur Vor- und  
514 Frühgeschichte in Baden-Württemberg, Stuttgart (K. Theiss), 53, 135-162.

515 Falkner G., Ripken T.E.J. and Falkner M., 2002. Mollusques continentaux de  
516 France. Liste de référence annotée et bibliographie. *Patrimoines Naturels*, 52,  
517 350 p.

518 Folmer O., Black M., Hoeh W., Lutz R. and Vrijenhoek R., 1994. DNA primers  
519 for amplification of mitochondrial cytochrome c oxidase subunit i from diverse  
520 metazoan invertebrates. *Molecular Marine Biology and Biotechnology*, 3, 294 -  
521 299.

522 Gavetti E., Birindelli S., Bodon M. and Manganelli G., 2008. Molluschi terrestri e  
523 d'acqua dolce della Valle di Susa. Monografie di Museo Regionale di Scienze  
524 Naturali, Torino 44, Beinasco, 274 p.

525 Geist J. and Kuehn R., 2005. Genetic diversity and differentiation of central  
526 European freshwater pearl mussel (*Margaritifera margaritifera* L.) populations:  
527 Implications for conservation and management. *Molecular Ecology*, 14, 425-439.

528 Germain, L., 1931. *Mollusques terrestres et fluviatiles. Faune de France*, Paris  
529 (Lechevalier), 477 p.

530 Gherardi F., Bertolino S., Bodon M., Casellato S., Cianfanelli S., Ferraguti M.,  
531 Lori E., Mura G., Nocita A., Riccardi N., Rossetti G., Rota E., Scalera R.,  
532 Zerunian S. and Tricarico E., 2008. Animal xenodiversity in Italian inland waters:  
533 Distribution, modes of arrival, and pathways. *Biological Invasions*, 10, 435-454.

534 Glöer P. and Zettler M. L., 2005. Kommentierte Artenliste der  
535 Süßwassermollusken Deutschlands. *Malakologische Abhandlungen*, 23, 3-26.

536 Haas F., 1969. *Superfamilia Unionacea*. *Das Tierreich*, 88, 663 p.

537 Hall T. A., 1999. BioEdit: a user-friendly biological sequence alignment editor  
538 and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series*,  
539 41, 95-98.

540 Huelsenbeck J. P., Ronquist F. and Hall B., 2001. MrBayes: Bayesian inference of  
541 phylogenetic trees. *Bioinformatics*, 17, 754-755.

542 IFEN, 2006. Les pesticides dans les eaux, données 2003 et 2004. *In*: F. Nirascou  
543 (Ed.), *Les Dossiers de l'IFEN*, Institut Français de l'Environnement, Orléans, 38p.

544 Keith P., Persat H., Feunteun E., Allardy J. (Eds.), 2011. *Les poissons d'eau*  
545 *douce de France*. Editions Biotope-Mèze and MNHN-Paris, 552 p.

546 Khalloufi N., Toledo C., Machordom A., Boumaïza M. and Araujo R., 2011. The  
547 unionids of Tunisia: Taxonomy and phylogenetic relationships, with redescription  
548 of *Unio ravoisieri* Deshayes, 1847 and *U. durieui* Deshayes 1847. *Journal of*  
549 *Molluscan Studies*, 77, 103-115.

550 Kottelat M. and Freyhof J., 2007. Handbook of European freshwater fishes.  
551 Published by the authors, 666 p.

552 Lydeard C., Cowie R. H., Ponder W. F., Bogan A. E., Bouchet P., Clark S. A.,  
553 Cumming K.S., Frest T.J., Gargominy O., Herbert D.G., Hershler R., Perez K.E.,  
554 Roth B., Seddon M., Strong E.E and Thompson F.G., 2004. The global decline of  
555 nonmarine mollusks. *BioScience*, 54, 321-330.

556 Mace, G. M., 2004. The role of taxonomy in species conservation. *Philosophical*  
557 *Transactions of the Royal Society of London*, 359, 711-719.

558 Machordom A., Araujo R., Erpenbeck D. and Ramos M.A., 2003.  
559 Phylogeography and conservation genetics of endangered European  
560 Margaritiferidae (Bivalvia: Unionoidea). *Biological Journal of the Linnean*  
561 *Society*, 78, 235–252.

562 Master L. L., Stein B. A., Kutner L. S. and Hammerson G. A. 2000. Vanishing  
563 assets: Conservation status of U.S. Species. *In*: Stein B. A., Kutner L. S. and  
564 Adams J. S. (Eds.), *Precious heritage: The status of biodiversity in the United*  
565 *States*, New York, Oxford University Press, 93-118.

566 May, R., 1990. Taxonomy as destiny. *Nature*, 347, 129-130.

567 McMurray S.E., Schuster G.A. and Ramey B.A., 1999. Recruitment in a  
568 freshwater unionid (Mollusca: Bivalvia) community downstream of Cave Run  
569 Lake in the Licking River, Kentucky. *American Malacological Bulletin*, 15, 57-  
570 63.

571 Morrison W. R., Lohr J. L., Duchen P., Wilches R., Trujillo D., Mair M. and  
572 Renner S.S., 2009. The impact of taxonomic change on conservation: Does it kill,  
573 can it save, or is it just irrelevant? *Biological Conservation* 142, 3201–3206.

574 Nagel K.O., 1992. Das Schalenwachstum dreier Muschelarten (Bivalvia:  
575 Unionidae) in der Schwalm, einem nordhessischen Mittelgebirgsfluß.  
576 *Decheniana*, 145, 165-176.

577 Nagel K.O., 2000. Testing hypotheses on the dispersal and evolutionary history of  
578 freshwater mussels (Mollusca: Bivalvia: Unionidae). *Journal of Evolutionary*  
579 *Biology*, 13, 854-865.

580 Nagel K.O. and Badino G., 2001. Population genetics and systematics of the  
581 European Unionidae. *In*: Bauer G. and Wächtler K., Ecology and Evolution of the  
582 Freshwater Mussels Unionidae, *Ecological Studies*, 1454, 51-81.

583 Ortmann A.E., 1920. Correlation of shape and station in freshwater mussels  
584 (Naiades). *Proceedings of the American Philosophical Society*, 59, 268-312.

585 Payraudeau B.-C., 1826. Catalogue descriptif et méthodique des Annélides et des  
586 Mollusques de l'île de Corse. Bechet, Levrault, Paschoud, Treuttel and Wurtz,  
587 Paris, 218 p.

588 Persat H. and Keith P., 2011. Biogéographie et historique de la mise en place des  
589 peuplements ichtyologiques de France métropolitaine. *In*: Keith P., Persat H.,

590 Feunteun E., Allardy J., Eds., Les poissons d'eau douce de France. Editions  
591 Biotope-Mèze and MNHN-Paris, 552 p.

592 Posada D., 2008. jModelTest: Phylogenetic Model Averaging. *Molecular Biology*  
593 *and Evolution*, 25, 1253-1256

594 Prié V., 2012. Les sous-espèces de la Mulette méridionale *mancus* Lamarck 1819  
595 (Bivalvia, Unionidea) en France : descriptions originales et matériel topotypique.  
596 *MalaCo*, 8, 19 p.

597 Ravera O., Frediani A. and Riccardi N., 2007. Seasonal variations in population  
598 dynamics and biomass of two *Unio pictorum mancus* (Mollusca, Unionidae)  
599 populations from two lakes of different trophic state. *Journal of Limnology*, 66,  
600 15-27.

601 Reis J. and Araujo R., 2009. Redescription of *Unio tumidiformis* Castro, 1885  
602 (Bivalvia, Unionidae), an endemism from the south-western Iberian peninsula.  
603 *Journal of Natural History*, 43, 1929-1945.

604 Sabater S., 2008. Alteration of the global water cycle and their effects on river  
605 structure, function and services. *Freshwater Reviews*, 1, 75-88.

606 Sabater S. and Tockner K., 2009. Effects of hydrologic alterations on the  
607 ecological quality of river ecosystems. *In*: Sabater S. and Barcelo D. (Eds), Water  
608 scarcity in the Mediterranean: Perspectives under global change, Springer Berlin /  
609 Heidelberg, 15-39.

610 Schonewald-Cox C.M., Chambers S.M., Macbryde B. and Thomas L., 1983.  
611 Genetics and conservation. Menlo Park, California: Benjamin/Cummings, 722 p.

612 Soroka M., 2010. Characteristics of mitochondrial DNA of unionid bivalves  
613 (Mollusca: Bivalvia: Unionidae). I. Detection and characteristic of double  
614 uniparental inheritance (DUI) of unionid mitochondrial DNA. *Folia*  
615 *Malacologica*, 18, 147-188.

616 Strayer D. L., 2006. Challenges for freshwater invertebrate conservation. *Journal*  
617 *of North American Benthological Society*, 25, 271-287.

618 Tamura K., Peterson D., Peterson N., Stecher G., Nei M. and Kumar S., 2011.  
619 MEGA5: Molecular Evolutionary Genetics Analysis using Maximum Likelihood,  
620 Evolutionary Distance, and Maximum Parsimony methods. *Molecular Biology*  
621 *and Evolution*, 28, 2731-2739.

622 Tockner K., Pusch M., Borchardt D. and Lorang M. S., 2010. Multiple stressors in  
623 coupled river–floodplain ecosystems. *Freshwater Biology*, 55, 135-151.

624 Watters G.T., 1994. Form and function of unionoidean shell sculpture and shape  
625 (Bivalvia). *American Malacological Bulletin*, 11, 1–20.

626 Zieritz A. and Aldridge D.C., 2009. Identification of ecophenotypic trends within  
627 three European freshwater mussel species (Bivalvia: Unionoida) using traditional  
628 and modern morphometric techniques. *Biological Journal of the Linnean Society*,  
629 98, 814–825.

630 Zieritz A., Hoffman J.I., Amos W. and Aldridge D.C., 2010. Phenotypic plasticity  
631 and genetic isolation-by-distance in the freshwater mussel *Unio pictorum*  
632 (Mollusca: Unionoida). *Evolutionary Ecology*, 24, 923-938.

633

634 Table I: Samples localities, MNHN numbers and GenBank accession numbers.

635 \*: type localities.

636

	Maritime Facade	Major drainage system	River	Species	Clade	Haplotype	Voucher n°	Genebank accession n°
Sequences produced for this paper	Atlantic	Adour	Loutz	<i>Unio mancus mancus</i>	1c	1	IM-2009-12598	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	1	IM-2009-12599	<i>En cours</i>
			Lake Brindos *	<i>Unio pictorum</i>	2	18	IM-2009-17835	<i>En cours</i>
				<i>Unio pictorum</i>	2	18	IM-2009-17836	<i>En cours</i>
				<i>Unio pictorum</i>	2	18	IM-2009-17837	<i>En cours</i>
				<i>Unio pictorum</i>	2	18	IM-2009-17838	<i>En cours</i>
				<i>Unio pictorum</i>	2	18	IM-2009-17839	<i>En cours</i>
			Gave de Pau	<i>Unio pictorum</i>	2	17	IM-2009-21214	<i>En cours</i>
				<i>Unio pictorum</i>	2	19	IM-2009-21215	<i>En cours</i>
		<i>Unio pictorum</i>		2	17	IM-2009-21216	<i>En cours</i>	
		Charente	Belle	<i>Unio mancus mancus</i>	1c	1	IM-2009-12710	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	1	IM-2009-12711	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	1	IM-2009-12713	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	1	IM-2009-12714	<i>En cours</i>
			Né	<i>Unio mancus mancus</i>	1c	1	IM-2009-12715	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-12716	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-12717	<i>En cours</i>
			Seugne	<i>Unio mancus mancus</i>	1c	3	IM-2009-12602	<i>En cours</i>
		<i>Unio mancus mancus</i>		1c	1	IM-2009-12604	<i>En cours</i>	
		Dordogne	Lary	<i>Unio pictorum</i>	2	17	IM-2009-12588	<i>En cours</i>
				<i>Unio pictorum</i>	3	17	IM-2009-12589	<i>En cours</i>
		Loire	Authion	<i>Unio mancus mancus</i>	1a	6	IM-2009-21274	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	1	IM-2009-21275	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	1	IM-2009-21276	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	6	IM-2009-21277	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	1	IM-2009-21278	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	6	IM-2009-21279	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	6	IM-2009-21280	<i>En cours</i>
<i>Unio mancus mancus</i>	1a			6	IM-2009-21281	<i>En cours</i>		
<i>Unio mancus mancus</i>	1a			6	IM-2009-21282	<i>En cours</i>		
<i>Unio mancus mancus</i>	1a		1	IM-2009-21283	<i>En cours</i>			
Boivre	<i>Unio mancus mancus</i>	1c	6	IM-2009-12591	<i>En cours</i>			



			Drée*	<i>Unio mancus mancus</i>	1c	6	IM-2009-21267	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-21268	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-21269	<i>En cours</i>
			Cher	<i>Unio mancus mancus</i>	1c	2	IM-2009-21293	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	4	IM-2009-21294	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-21295	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-21296	<i>En cours</i>
				<i>Unio pictorum</i>	2	17	IM-2009-21297	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-21298	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	1	IM-2009-21299	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	2	IM-2009-21300	<i>En cours</i>
				<i>Unio pictorum</i>	2	17	IM-2009-21301	<i>En cours</i>
			Vonne	<i>Unio mancus mancus</i>	1c	1	IM-2009-12666	<i>En cours</i>
	<i>Unio mancus mancus</i>	1c		1	IM-2009-12667	<i>En cours</i>		
	<i>Unio mancus mancus</i>	1c		6	IM-2009-12668	<i>En cours</i>		
	Aër	Ellé	<i>Unio mancus mancus</i>	1c	6	IM-2009-17787	<i>En cours</i>	
			<i>Unio mancus mancus</i>	1c	6	IM-2009-17788	<i>En cours</i>	
	Atlantic via Manche	Blez Jean	Beaufort	<i>Unio mancus mancus</i>	1a	5	IM-2009-21302	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	5	IM-2009-21303	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	5	IM-2009-21304	<i>En cours</i>
				<i>Unio mancus mancus</i>	1a	5	IM-2009-21305	<i>En cours</i>
<i>Unio mancus mancus</i>				1a	5	IM-2009-21306	<i>En cours</i>	
<i>Unio mancus mancus</i>				1a	5	IM-2009-21307	<i>En cours</i>	
Seine		Aisne	<i>Unio pictorum</i>	2	17	IM-2009-17764	<i>En cours</i>	
			<i>Unio pictorum</i>	2	17	IM-2009-17798	<i>En cours</i>	
			<i>Unio pictorum</i>	2	17	IM-2009-17799	<i>En cours</i>	
			<i>Unio pictorum</i>	2	17	IM-2009-17801	<i>En cours</i>	
			<i>Unio pictorum</i>	2	17	IM-2009-17802	<i>En cours</i>	
		Armance	<i>Unio pictorum</i>	0	19	IM-2009-21250	<i>En cours</i>	
		Eure	<i>Unio pictorum</i>	1	23	IM-2009-21285	<i>En cours</i>	
			<i>Unio pictorum</i>	2	23	IM-2009-21286	<i>En cours</i>	
			<i>Unio pictorum</i>	2	17	IM-2009-21287	<i>En cours</i>	
		Oise	<i>Unio pictorum</i>	2	21	IM-2009-12688	<i>En cours</i>	
		Ourcq	<i>Unio mancus requienii</i>	1b	13	IM-2009-21218	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-21222	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-21224	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-21228	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-21229	<i>En cours</i>	

				<i>Unio mancus requienii</i>	1b	13	IM-2009-21231	<i>En cours</i>
				<i>Unio mancus requienii</i>	1b	13	IM-2009-21233	<i>En cours</i>
				<i>Unio pictorum</i>		23	IM-2009-21234	<i>En cours</i>
				<i>Unio mancus requienii</i>	1b	13	IM-2009-21235	<i>En cours</i>
				<i>Unio pictorum</i>	2	23	IM-2009-21236	<i>En cours</i>
			Petit Morin	<i>Unio mancus requienii</i>		11	IM-2009-17803	<i>En cours</i>
				<i>Unio mancus requienii</i>	1b	13	IM-2009-17810	<i>En cours</i>
				<i>Unio mancus requienii</i>	1b	13	IM-2009-17812	<i>En cours</i>
				<i>Unio mancus requienii</i>		12	IM-2009-17813	<i>En cours</i>
				<i>Unio mancus requienii</i>	1b	13	IM-2009-17814	<i>En cours</i>
			Seine	<i>Unio mancus requienii</i>	1b	13	IM-2009-21242	<i>En cours</i>
				<i>Unio mancus requienii</i>	1b	13	IM-2009-21245	<i>En cours</i>
				<i>Unio pictorum</i>	2	21	IM-2009-12695	<i>En cours</i>
				<i>Unio pictorum</i>	2	17	IM-2009-12696	<i>En cours</i>
				<i>Unio pictorum</i>	2	17	IM-2009-12697	<i>En cours</i>
	Somme	Somme Canal	<i>Unio pictorum</i>	2	17	IM-2009-17771	<i>En cours</i>	
			<i>Unio pictorum</i>	2	21	IM-2009-17772	<i>En cours</i>	
	Mediterranean	Argens	Argens	<i>Unio mancus turtonii</i>	1a	9	IM-2009-12571	<i>En cours</i>
				<i>Unio mancus turtonii</i>	1a	10	IM-2009-12579	<i>En cours</i>
		Basse	Basse*	<i>Unio mancus mancus</i>	1c	6	IM-2009-17815	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-17816	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-17817	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-17818	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-17819	<i>En cours</i>
				<i>Unio mancus mancus</i>	1c	6	IM-2009-17820	<i>En cours</i>
Hérault		Hérault	<i>Unio mancus requienii</i>	1b	14	IM-2009-12569	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-12572	<i>En cours</i>	
		Lamalou	<i>Unio mancus requienii</i>	1b	14	IM-2009-12570	<i>En cours</i>	
Rhône		Ardèche	<i>Unio mancus requienii</i>	1b	13	IM-2009-12582	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-12701	<i>En cours</i>	
		Lake Bourget*	<i>Unio pictorum</i>	2	17	IM-2009-12703	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-12704	<i>En cours</i>	
			<i>Unio pictorum</i>	2	17	IM-2009-12705	<i>En cours</i>	
			<i>Unio mancus requienii</i>	1b	13	IM-2009-12706	<i>En cours</i>	
		Cèze	<i>Unio mancus requienii</i>	1b	15	IM-2009-12708	<i>En cours</i>	
	<i>Unio mancus requienii</i>		1b	13	IM-2009-12581	<i>En cours</i>		
Lake Gravière*	<i>Unio mancus requienii</i>	1b	13	IM-2009-17775	<i>En cours</i>			

			Rhône	<i>Unio mancus requienii</i>	1b	13	IM-2009-12605	<i>En cours</i>	
			Suran	<i>Unio mancus requienii</i>	1b	13	IM-2009-12699	<i>En cours</i>	
				<i>Unio mancus requienii</i>	1b	14	IM-2009-17806	<i>En cours</i>	
				<i>Unio mancus requienii</i>	1b	13	IM-2009-17807	<i>En cours</i>	
				<i>Unio mancus requienii</i>	1b	14	IM-2009-17808	<i>En cours</i>	
				<i>Unio mancus requienii</i>	1b	13	IM-2009-17809	<i>En cours</i>	
		Corsica	Fium Orbu*	<i>Unio mancus turtonii</i>	1a	9	IM-2009-12735	<i>En cours</i>	
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12736	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12737	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12738	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12739	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12740	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12747	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12748	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	8	IM-2009-12749	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12751	<i>En cours</i>
				<i>Unio mancus turtonii</i>	1a	9	IM-2009-12754	<i>En cours</i>	
				Golo*	<i>Unio mancus turtonii</i>	1a	9	IM-2009-17784	<i>En cours</i>
				Taravu*	<i>Unio mancus turtonii</i>	1a	9	IM-2009-12725	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12726	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12727	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12728	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12729	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12730	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12731	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12732	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12733	<i>En cours</i>
				Taviganu*	<i>Unio mancus turtonii</i>	1a	9	IM-2009-12734	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12758	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12759	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12760	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12761	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-12762	<i>En cours</i>
					<i>Unio mancus turtonii</i>	1a	9	IM-2009-21815	<i>En cours</i>
				<i>Unio mancus turtonii</i>	1a	9	IM-2009-17750	<i>En cours</i>	
				<i>Unio mancus turtonii</i>	1a	9	IM-2009-17751	<i>En cours</i>	
			Pô	Lake Maggiore	<i>Unio elongatulus</i>	3	16	IM-2009-12673	<i>En cours</i>
						<i>Unio elongatulus</i>	3	16	IM-2009-12674

				<i>Unio elongatulus</i>	3	16	IM-2009-12675	<i>En cours</i>
	Northern Sea	Meuse	Meuse	<i>Unio pictorum</i>	2	22	IM-2009-12573	<i>En cours</i>
				<i>Unio pictorum</i>	2	17	IM-2009-12574	<i>En cours</i>
				<i>Unio pictorum</i>	2	22	IM-2009-12576	<i>En cours</i>
				<i>Unio pictorum</i>	2	17	IM-2009-12577	<i>En cours</i>
Genebank sequences	North Sea (Poland)			<i>Unio pictorum</i>	2	13	?	AF468684.2
				<i>Unio pictorum</i>	2	14	233	EU548056.1
				<i>Unio pictorum</i>	2	19	253	EU548057.1
	Mediterranean (Spain)			<i>Unio mancus mancus</i>	1c	7	Fw1238-15	AY522847.1
				<i>Unio mancus mancus</i>	1c	7	Fw1238-18	AY522848.1
				<i>Unio mancus mancus</i>	1c	7	Fw1487-1	AY522849.1
				<i>Unio mancus mancus</i>	1c	7	Fw1487-2	AY522850.1
				<i>Unio mancus mancus</i>	1c	7	Fw1487-3	AY522851.1
				<i>Unio mancus mancus</i>	1c	7	Fw1487-4	AY522852.1
				<i>Unio mancus mancus</i>	1c	7	Fw1487-5	AY522853.1
				<i>Unio mancus mancus</i>	1c	7	Fw1535-N1	AY522854.1
				<i>Unio mancus mancus</i>	1c	7	Fw1536-N2	AY522855.1
				<i>Unio mancus mancus</i>	1c	6	Fw1544-N50	AY522856.1
				<i>Unio mancus mancus</i>	1c	6	Fw1545-N53	AY522857.1
<i>Unio mancus mancus</i>	1c	7	Fw1585-N250	AY522858.1				
Outgroups (own sequences)	North Sea	Meuse	Meuse	<i>Unio tumidus</i>			IM-2009-12575	<i>En cours</i>
	Atlantic	Loire	Vienne	<i>Unio crassus</i>			IM-2009-12564	<i>En cours</i>
				<i>Margaritifera auricularia</i>			IM-2009-12611	<i>En cours</i>

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639 Figure captions

640 Figure 1: Distribution of *Unio mancus* subspecies in France according to Falkner  
641 *et al.* (2002) (red dotted lines). Type localities are indicated by grey squares.  
642 Localities sampled for this study are represented by green dots.

643

644 Figure 2: Bayesian phylogenetic tree of French and Spanish populations of *U.*  
645 *mancus*, *U. elongatulus* and *U. pictorum*. Posterior probabilities are indicated for  
646 each node (when > 0.70). H1 to H23: haplotype numbers. Rivers are given after  
647 haplotypes numbers. Black lines link up haplotypes from the same locality.  
648 Clades 1, 2 and 3 and groups 1a, 1b and 1c are highlighted.

649 Blue = clade 1a, red = clade 1b, orange = clade 1c, purple = *U. mancus*, green =  
650 *U. elongatulus*, yellow = *U. pictorum*.

651

652 Figure 3: Putative distribution of the subspecies of *U. mancus* inferred from main  
653 drainage systems. Blue, *U. m. mancus*; orange, *U. m. requienii*; red, *U. m. turtonii*.  
654 Yellow circles, *U. pictorum* sample sites; green circle, *U. elongatulus* sample site.

655

656 Figure 4: Morphological variability of *U. mancus* in France.

657 A: *U. m. mancus*, lectotype. River Drée, Bourgogne, MNHN 24632; B: *U. m.*  
658 *mancus*, River Vonne at Soudan (Loire-Atlantique), MNHN IM-2009-12668; C:  
659 *U. m. mancus*, River Ellé at Meslan (Morbihan), MNHN IM-2009-17788; D: *U.*  
660 *m. mancus*, River Basse at Toulouges (Pyrénées-Orientales), MNHN IM-2009-  
661 17815; E: *U. m. mancus*, River Loutz at Lacajunte (Landes), MNHN IM-2009-

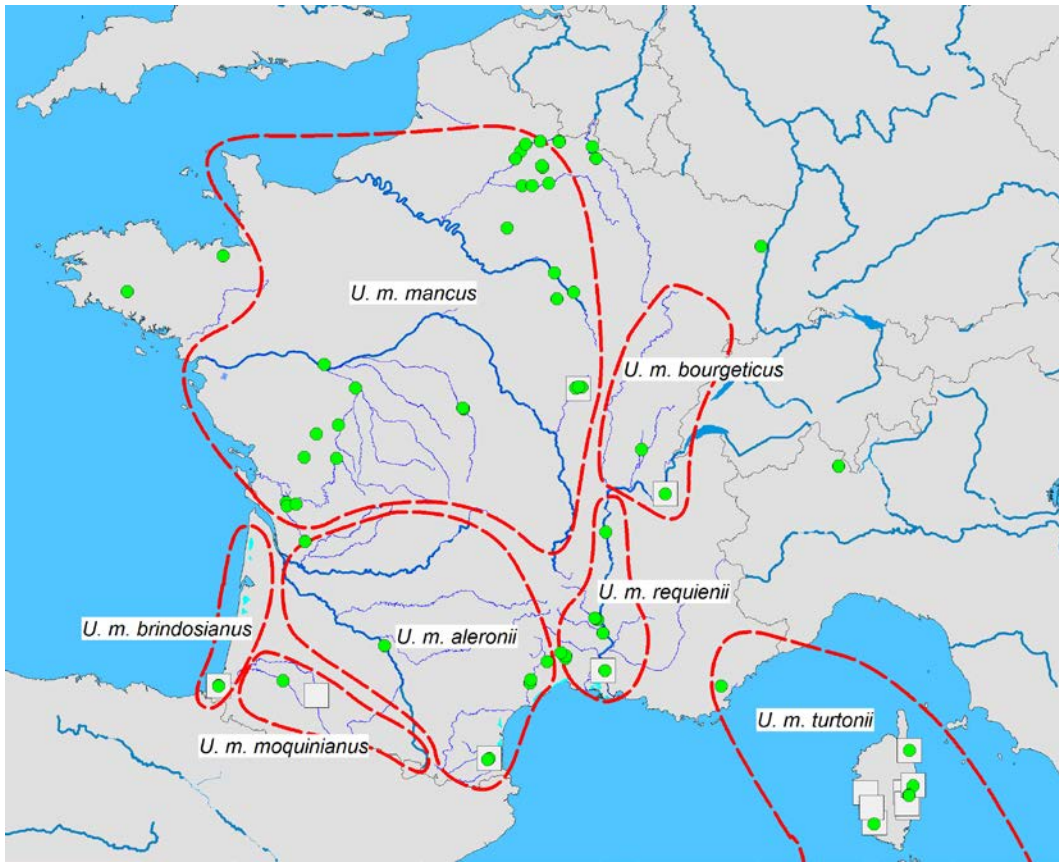
662 12599; F: *U. m. requienii*, River Aisne at Bourg-et-Comin (Aisne), MNHN IM-  
663 2009-17803; G: *U. m. requienii*, Lake Bourget at Chindrieux (Savoie), MNHN  
664 IM-2009-12701; H: *U. m. requienii*, Lake Bourget at Chindrieux (Savoie),  
665 MNHN IM-2009-12707; I: *U. pictorum*, Lake Bourget at Chindrieux (Savoie),  
666 MNHN IM-2009-12703; J: *U. pictorum*, Lake Bourget at Chindrieux (Savoie),  
667 MNHN IM-2009-12705; K: *U. bourgeticus*, syntype, MNHN 22139; L: *U.*  
668 *mancus requienii*, possible topotype, Lake Gravières at Arles (Bouches-du-  
669 Rhône), MNHN IM-2009-17775; M: *U. mancus requienii*, River Rhône at  
670 Sablons (Isère), MNHN IM-2009-12605; N: *U. mancus requienii*, River Hérault  
671 at Bélarga (Hérault), MNHN IM-2009-12569; O: *U. mancus turtonii*, River Orbu  
672 at Ghisonaccia (Haute-Corse), MNHN IM-2009-12736; P: *U. mancus turtonii*,  
673 River Argens at Le Muy (Var), MNHN IM-2009-12579.

674 All specimens with an IM catalog number prefix are sequenced vouchers.

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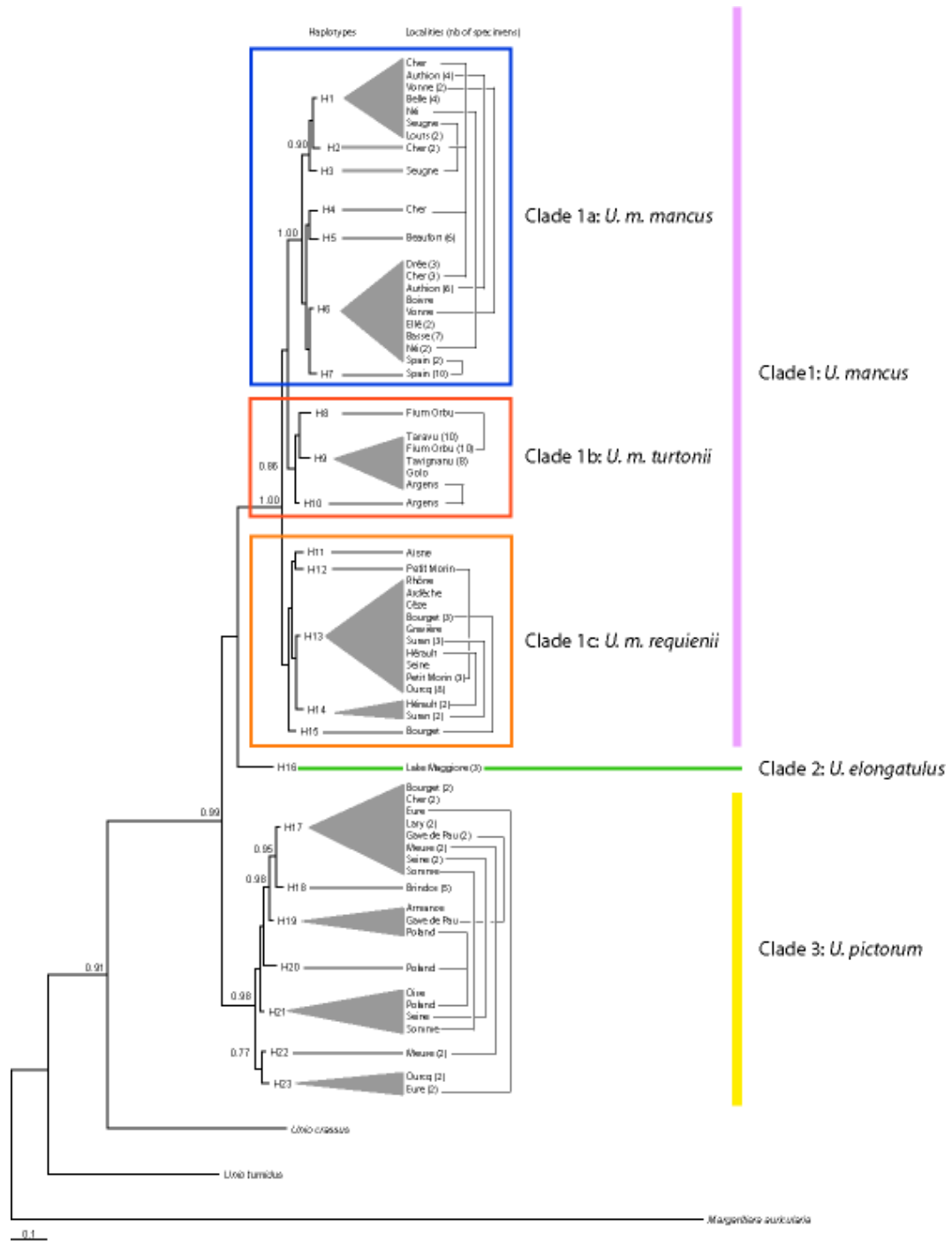
677 Figure 1



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680 Figure 2



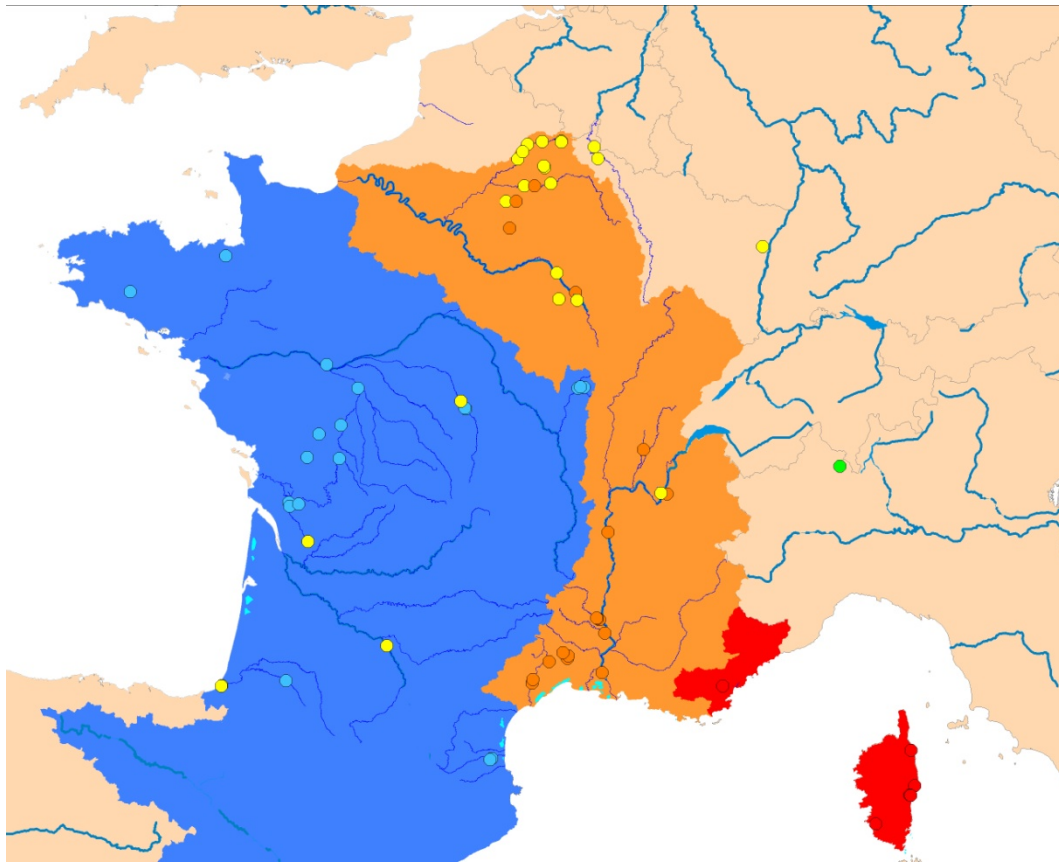
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684 Figure 3



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