

leaves. It differs from species in group C in having bicolorous glumes, lower-half plumose perianth members and curling leaves (also see Table 3.1).

The present study (Figs 3.1, 3.3, 3.4, 3.5, 3.9) confirms the recognized species limits of *Carpha rodwayi*, *C. curvata*, *C. borbonica* and *C. filifolia* (Kükenthal 1939c; Curtis 1984; Reid and Arnold 1984; Hilliard 1987; Hilliard and Burt 1987; Curtis and Morris 1994; Gordon-Gray 1995). The cases for other species of *Carpha* are discussed below.

*Carpha nivicola* was first described by Mueller (1855). It was included later in *C. alpina* by Mueller (1875) himself, and he was followed in this by some subsequent authors (e.g. Bentham 1878; Pfeiffer 1931; Kükenthal 1939c). But some other authors (Blake 1940; Costin et al. 1979; Thompson 1981; Thompson and Gray 1981; Wilson 1993, 1994a, 1994b) regarded it as being different from *C. alpina*. Phenetic analyses in this study separated its specimens from specimens of *C. alpina* (Figs 3.1, 3.3 and 3.4), and indicated it should be recognized as a species, i.e. supported the latter view. *Carpha nivicola* differs from *C. alpina* by its large spikelets, flowers and nuts, and wide leaves (Table 3.2).

*Carpha schoenoides* was treated as a variety of *C. alpina* by some authors (Kükenthal 1939c; Barros 1969), while it was synonymised with *C. alpina* by others (Philippi 1881; Clarke 1901; Pfeiffer 1931; Gunckel 1971, Moore 1983). This study (Figs 3.1, 3.3 and 3.4) showed that it should be recognized as a species as was done by Hooker (1847), Steudel (1855) and Philippi (1881). This species differs from the other four species of *Carpha sensu stricto* in having two flowers per spikelet, both of which produce a nut, and having a nut epidermis sculpture that is not punctulate (Table 3.2; also see Fig. 6.3 d). *Carpha schoenoides* is restricted to South America, and is disjunct from other species of *Carpha*.

When *Carpha nivicola* and *C. schoenoides* are delimited as species, the limits of *Carpha alpina* become clear.

Kükenthal (1939d) treated *Carpha angustissima* as a variety of *C. eminii*, and this was followed by Napper (1964), but the present analyses (Figs 3.1, 3.5, 3.6 and 3.7) indicate that it should be maintained as a species in line with Chermeson (1935) and Haines and Lye (1983). *Carpha angustissima* differs from *C. eminii* by usually having two flowers per spikelet, 'rachilla' elongated above the fertile glumes and adnate to the fertile glume base,

and leaf blades thinly crescentiform in cross-section (Table 3.3, also see Fig. 2.2 k (rarely e) for spikelet structure).

After *Carpha angustissima* is delimited as a species, the limits of *C. eminii* become clear.

When Clarke (1894) published his new species *C. bracteosa*, he cited three specimens (*Bolus* 2867, *MacOwan* 1616, 2187). I examined these syntypes and found their morphology to be heterogeneous. *Bolus* 2867 (Fig. 3.10) has keeled leaves, V-shaped in cross-section, and inflorescences with ovate bracts that lack long apices and that are more or less equal in length to the head of spikelets. Spikelets are clustered in ovoid heads, and the surface of the nuts is reticulate (see Fig 6.6 a, b). In contrast, *MacOwan* 1616 and 2187 (Fig. 3.11) have leaves without a keel, thickly crescentiform to circular in cross-section, and inflorescences with ovate bracts that have long acuminate apices and that are 2–10 cm longer than the heads of spikelets. Spikelets form oblong heads, and the surface of the nuts is reticulate with punctulate centres (Fig. 3.12). Other more recent specimens identified as *C. bracteosa* showed the same differences as those above. In the analyses, specimens matching *Bolus* 2867 were named *C. bracteosa*, and specimens matching *MacOwan* 1616 and 2187 were assigned to *C. cf. bracteosa*, because the shape of bracts in *Bolus* 2867 is more suitable for the name *C. bracteosa* than is the case in *MacOwan* 1616 and 2187. The results of the analyses (Figs 3.1, 3.5, 3.6) clearly indicated that *C. cf. bracteosa* should be segregated from *C. bracteosa* and recognized as a new species. This species is different from all other species of *Carpha* in having ovate bracts with long apices. A description is presented in Chapter 6.

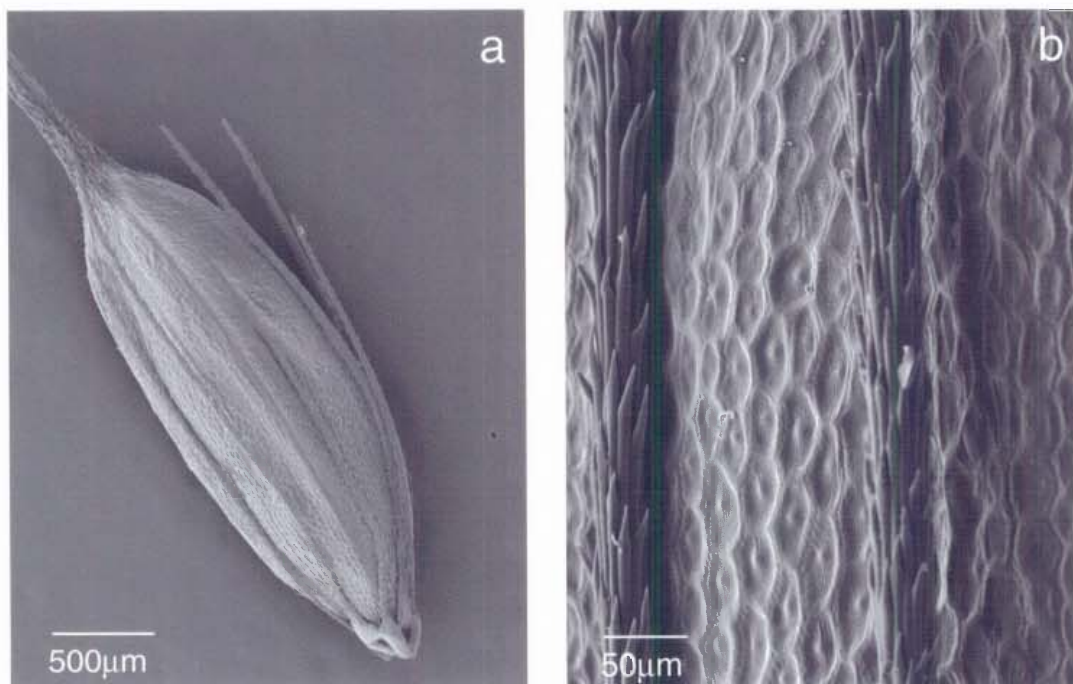
Kükenthal (1939c) treated *C. bracteosa* as a variety of *C. capitellata* and Levyns (1950) synonymised it with *C. capitellata*, while other authors (Clarke 1894, 1897–1898, 1904; Pfeiffer 1931; Reid and Arnold 1984; Browning and Guthrie 1994) recognized it as a separate species. In this study, its specimens always formed a subgroup with the specimens of *C. capitellata* (Figs 3.1, 3.5), suggesting that *C. bracteosa* should not be a species because of its lower dissimilarity with *C. capitellata*. But it differs from *C. capitellata* because its specimens consistently formed a secondary subgroup within the subgroup. *Carpha bracteosa* and *C. capitellata* do not isolate geographically and have the same habitat. Thus, *C. bracteosa* should be treated as a variety. It differs from *C. capitellata* in having ovate bracts subtending the heads of spikelets.



**Fig. 3.10.** Specimen *Bolus 2867* (K). A syntype of *Carpha bracteosa* C.B. Clarke and selected as lectotype of *Carpha capitellata* (Nees) Boeck. var. *bracteosa* (C.B. Clarke) Kük. in Chapter 6. See Appendix 1 for detailed collecting information.



**Fig. 3.11.** Specimen MacOwan 2187 (K). A syntype of *Carpha bracteosa* C.B. Clarke, here separated as a new species. See Appendix 1 for detailed collecting information.



**Fig. 3.12.** SEM micrographs of fruit of specimen *MacOwan 2187* (K), a syntype of *Carpha bracteosa* C.B.Clarke, here separated as a new species. See Appendix 1 for detailed collecting information. **a**, Fruit with six bristles. **b**, Epidermis of fruit showing reticulate cell outlines with punctulate centres.

*Carpha perrieri* from Madagascar was described by Chermezon (1922). He thought *C. perrieri* was close to *C. capitellata* from the Cape Province of South Africa in its habit, but differed from *C. capitellata* by its slightly bigger glumes, its longer hypogynous perianth, its larger style base, and its narrower nut ('Voisin par son port de *C. capitellata* Boeck., du Cap, dont il diffère notamment par ses glumes un peu plus grandes, ses soies hypogynes plus longues, son style à base plus développée, et son achène plus étroit.' — Chermezon 1922, p. 722). In fact, measurements of these characters from these two species overlap (Table 3.4) and specimens of the two species cannot be distinguished from each other except in terms of locality. Not surprisingly, specimens of the two species form a single group in the analyses (Figs 3.1, 3.5, 3.6, 3.7 and 3.8). *Carpha perrieri* should be combined with *C. capitellata*.

**Table 3.4.** Comparison of supposed diagnostic characters for *Carpha capitellata* and *C. perrieri*. See text for discussion.

Character (units)	<i>C. capitellata</i>	<i>C. perrieri</i>
Lower fertile glume length (mm)	4.4–6.0	4.8–6.8
Upper fertile glume length (mm)	4.2–5.9	3.2–6.5
Longest hypogynous bristle length (mm)	1.5–3.1	2.0–3.5
Style base length (mm)	0.3–0.7	0.3–0.9
Nut diameter (mm)	0.8–1.1	0.8–1.1

*Carpha nitens* (Kunth) Kük. differs from other species of *Carpha* by its keeled leaves, spikes that are narrow-oblong and loose, and in being restricted to Réunion (Fig. 3.13). Examination of specimens of *C. nitens* from Réunion revealed that some have dense spikes, although they have keeled leaves and spikes that are narrow-oblong, and they were referred to as *C. cf. nitens* in the phenetic analyses. Specimens from the Ulugurus Mountains in Tanzania are a close match for *C. cf. nitens* except for the size of some vegetative and some reproductive parts. In the phenetic analyses these specimens were labelled *C. ulugurensis* according to the manuscript name of Nelmes. The analyses of clustering (Figs 3.1 and 3.5) clearly indicated that *C. cf. nitens* and *C. ulugurensis* should be segregated from *C. nitens* and recognized as a new species, although they were separated as two subgroups in ordination (Figs 3.6 and 3.8) that, however, is not contradictory to the result of the clustering. This new species is different from *C. nitens* in that spikelets form dense oblong heads (Table 3.3). A description is presented in Chapter 6.



**Fig. 3.13.** A typical specimen of *Carpha nitens* (J. E. Coode 4186, K; see Appendix 1 for detailed collecting information).

*Carpha schlechteri* was first described by Clarke (1904, p. 37) as ‘*C. glomerata* Nees affinis; differt: foliis angustioribus (vix 5 mm. latis); inflorescentia graciliore, spiculis minoribus; nuce grosse conspicue hexagono-reticulata levi (neque, ut in *C. glomerata*, minute obscure reticulata)’. He did not mention how big the spikelet and the nut of *C. schlechteri* were in his description. Later, he (1908) noted that *C. schlechteri* has leaves 4–5 mm wide, and nuts 2–2.5 mm. My examination of the type collection (*R. Schlechter 10010*, sheets in K, BOL 63205, NSW, P 00199388, PRE and Z) found the leaves to be 4.5–6 mm wide. Some specimens (such as *J. Browning 823*, NU) matched the type and had nuts 2–2.5 mm long but leaves up to 8 mm wide.

The protologues of *Carpha glomerata* (Nees 1832), *Schoenus glomeratus* (Thunberg 1794) or *Asterochaete glomerata* (Nees 1834; he only transferred the name without any description in 1834, but he gave a description in 1835) did not describe leaf width and nut length. The type of *Carpha glomerata* (*Schoenus glomeratus* or *Asterochaete glomerata*) is not available. A photocopy of syntypes (the *Thunberg 1344, 1345* specimens of *Schoenus glomeratus*) from the microfiche of Thunberg’s herbarium were obtained. However, there is no scale on them. The leaf width of *C. glomerata* was first described by Boeckeler (1874, p. 265) as ‘7–12 lin. Lat.’ (c. 14.8–25.4 mm wide). But Clarke (1897–1898) described the leaf width of *C. glomerata* as ¼ in. (c. 6.4 mm) or more. The recent literature is not consistent on these issues. Levyns (1950) described the leaves of *C. glomerata* as 2 cm wide, Haines and Lye (1983) recorded it as having leaves 4–6 mm wide and nuts 2.4–2.6 mm long. Gordon-Gray (1995) listed its leaves as 15–28 mm wide.

Contrary views on how to distinguish *C. schlechteri* and *C. glomerata* exist. Kükenthal (1939c) considered that *C. glomerata* had leaves 5–12 mm wide, spikelets 6–8 mm long and nuts 3.5 mm long, while *C. schlechteri* had leaves 4–5 mm wide, spikelets 4 mm long and nuts 2.5 mm long. Reid and Arnold (1984) found that *C. schlechteri* differed from *C. glomerata* by its less robust stature, and that its leaves were 5–8 mm wide, while the leaves of *C. glomerata* were 15–28 mm wide.

The protologue of *C. schlechteri* does not totally match the type specimens, while *C. glomerata* was not described in detail in its protologue and its type specimen is not available. The literature provides inconsistent definitions of *C. schlechteri* and



*C. glomerata*. As a result, it is difficult to identify some specimens of these two species. In this study, specimens with a less robust stature, and with leaves 4.5–8 mm wide that match or almost match the type specimen of *C. schlechteri* were named as *C. schlechteri*, while specimens of a robust stature and with leaves 13–24 mm wide that are markedly different from the type specimens of *C. schlechteri* and match the outline of the photocopy of syntypes of *C. glomerata* (the Thunberg 1344, 1345 specimens of *Schoenus glomeratus*) from the microfiche of Thunberg’s herbarium were labelled as *C. glomerata*.

I found most specimens of *C. schlechteri* match the type in having spikelets with a male flower below a bisexual flower (and spikelets that mature only one nut) and the ‘rachilla’ not elongated above the proximal fertile node (Fig 2.2; Table 2.1), while some specimens of *C. schlechteri* have two bisexual flowers per spikelet (both flowers develop nuts) and the ‘rachilla’ is elongated above the proximal fertile node (Fig 2.2; Table 2.1). All specimens of *C. glomerata* as recognized here have two bisexual flowers per spikelet (both flowers develop nuts) and the ‘rachilla’ is elongated above the proximal fertile node (Fig 2.2; Table 2.1). In the phenetic analyses (Figs 3.1, 3.5, 3.6, and 3.9) one specimen initially identified as *C. schlechteri* (*B. Sonnenberg 458*, NU), which has two bisexual flowers per spikelet (both flowers develop nuts) and an elongated ‘rachilla’ internode above the proximal fertile node (Fig 2.2; Table 2.1), was grouped with specimens of *C. glomerata* despite its less robust stature and narrower leaves. All other specimens of *C. schlechteri*, which have a male flower below a single bisexual flower per spikelet and the ‘rachilla’ not elongated above the proximal fertile node, were grouped together. Thus, the definitions of *C. glomerata* and *C. schlechteri* need to be revised to take spikelet characters into account. *C. glomerata* as recognized here has two bisexual flowers per spikelet, both of which mature a nut, and the ‘rachilla’ is elongated above the proximal fertile node, while *C. schlechteri* has spikelets with a proximal male flower, one bisexual flower, and a ‘rachilla’ that does not elongate above the proximal fertile node. The plants of *C. schlechteri* are usually less robust and generally have narrower leaves than in *C. glomerata*.

This study has led to the recognition of 16 species in *Carpha sensu lato* (Table 3.5) and clarified the limits of these species. Three (*C. cf. bracteosa*, *C. ulugurensis* and *C. discolor*) are new species; the taxonomic rank of *C. angustissima*, *C. capitellata* var. *bracteosa* and *C. schoenoides*, for which there had been some disagreement, is delimited;

*C. perrieri* is synonymised with *C. capitellata*; the definitions of *C. schlechteri* and *C. glomerata* are revised. A detailed taxonomic review of *Carpha* is presented in Chapter 6.

**Table 3.5.** Species of *Carpha sensu lato* recognized before and after phenetic analyses.

Species before analysis	Species after analysis
<i>C. alpina</i>	<i>C. alpina</i>
<i>C. angustissima</i> ( <i>C. eminii</i> var. <i>angustissima</i> )	<i>C. angustissima</i>
<i>C. borbonica</i>	<i>C. borbonica</i>
<i>C. bracteosa</i> ( <i>C. capitellata</i> var. <i>bracteosa</i> )	<i>C. capitellata</i> var. <i>bracteosa</i>
<i>C. cf. bracteosa</i>	<i>C. species nov.</i>
<i>C. capitellata</i>	<i>C. capitellata</i> var. <i>capitellata</i>
<i>C. perrieri</i>	
<i>C. curvata</i>	<i>C. curvata</i>
<i>C. discolor</i> ms	<i>C. species nov.</i>
<i>C. eminii</i>	<i>C. eminii</i>
<i>C. filifolia</i>	<i>C. filifolia</i>
<i>C. glomerata</i>	<i>C. glomerata</i>
<i>C. nitens</i>	<i>C. nitens</i>
<i>C. cf. nitens</i>	<i>C. species nov.</i>
<i>C. ulugurensis</i> ms	
<i>C. nivicola</i>	<i>C. nivicola</i>
<i>C. rodwayi</i>	<i>C. rodwayi</i>
<i>C. schlechteri</i>	<i>C. schlechteri</i>
<i>C. schoenoides</i> ( <i>C. alpina</i> var. <i>schoenoides</i> )	<i>C. schoenoides</i>