Water plants of the World

by C. D. K. Cook

Dr. W. Junk by Publishers The Hague

WATER PLANTS O

A manual for the identification of the genera of freshwater macrophytes

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Dr. W. Junk b.v., Publishers, The Hague 1974

PREFACE

Freshwater macrophytes play a very important role in aquatic ecosystems. They provide, either directly or indirectly, food, shelter and a variety of habitats for a large number of organisms, including wildfowl and economically important fish. It must be mentioned that rice, an aquatic plant, is the most important single crop species in the world. Many other aquatic plants are also of direct use to man as food, raw materials for industrial processes, building materials and manure in agriculture. Aquatic plants absorb dissolved minerals and enrich water with oxygen produced during photosynthesis. These properties are of benefit to man as they assist in the maintenance of clean water and the help in the recovery of polluted water. However, in disturbed or newly constructed bodies of water rampant growth of aquatic plants may interfere with man's use of freshwater. They may obstruct water-flow, navigation or water intakes: they may interfere with fish production and crops in aquatic environments or on irrigated land; they may also create conditions favourable for pests, diseases and vectors affecting humans, animals and crop plants; they may also upset recreation pursuits.

Before one can communicate any information about a particular plant it must be identified and named. The name of a plant is the key to all we know about it. Unfortunately, the identification of aquatic plants is particularly difficult. Firstly, aquatic plants are easily modified by environmental conditions and they are frequently found without reproductive structures. This often makes it difficult to determine which group or groups they belong to because the present classification of plants is largely based on reproductive structures and so are the manuals for their identification. Secondly, aquatic plants are often very mobile and are constantly leaving or invading new areas with the consequence that local Floras are often out of date. Thirdly, it would appear that botanists on the whole do not like getting their feet wet because the state of knowledge on aquatics, in comparison to other plant groups, is very incomplete. With these difficulties in mind it was recommended at a meeting of experts on the ecology and control of aquatic vegetation convened by UNESCO through the Co-ordinating Council for the IHD (International Hydrological Decade) with the IBP (International Biological Programme) at Paris in December 1968 that a manual for the identification of aquatic plants on a world-wide scale should be written. I agreed to undertake this task.

This work has been designed chiefly to be a source for the identification of all genera of aquatic macrophytes. It is intended that the non-botanist should be able to use this manual, therefore all genera have been illustrated, the botanical terminology has been kept to a minimum and where ever possible vegetative features and easily seen floral characters have been used in keys and descriptions.

Notes on distribution, number of species, ecology and uses have been given and selected references for the identification of species within the genera have been cited where they are of value to the user.

The fonds national suisse de la recherche scientifique generously supplied a grant* for three years for a plant illustrator and a full-time post-doctoral research fellow. From 1970 to 1971 the research fellowship was filled by Bernardo J. Gut and from 1971 to 1973 by E. Martyn Rix. It is difficult to single out the particular parts undertaken by each co-worker as the project has been essentially team work and each has modified the final draft. Jakob Schneller, an assistant of the Institute for Systematic Botany of the University of Zürich wrote and illustrated the part on aquatic mosses and contributed to the final preparation stages.

Most of the illustrations are by Marta Seitz, initialed "MS". Jakob Schneller illustrated the mosses, initialed "JS" and I have contributed a few illustrations, initialed "CC". I would very much like to thank the co-workers for their efforts and humour in times of crisis. Thanks are also due to the Co-ordinating Council for the IHD (UNESCO) and the Council of the "Georges and Antoine Claraz-Schenkung" for financial assistance for fieldwork. The following institutions kindly and very promptly lent us herbarium material: Conservatoire et Jardin Botanique Genève, Royal Botanic Gardens Kew, Botanische Staatssammlung München, Smithsonian Institution Washington and Eidgenössische Technische Hochschule Zürich. I would like to thank the following for help, either with their specialist knowledge or for sending plant material: R. C. Bakhuizen van den Brink (Leiden), F. D. Bennett (Trinidad), H. W. E. van Bruggen (Heemskerk), W. D. Clayton (Kew), W. G. Dore (Ottawa), J. B. Hall (Ghana), B. Hellquist (Boston), S. Hooper (Kew), D. J. Keil (Ohio), N. G. Marchant (Perth, Australia), H. Merxmüller (München), R. van der Meijden (Leiden), D. S. Mitchell (Salisbury, Rhodesia), H. Moldenke (New Jersey), P. Raven (St. Louis), V. P. Rao (Bangalore), P. Schneider (Zuzgen, Switzerland), R. M. Schuster (Massachusetts), C. G. G. J. van Steenis (Leiden) and P. Taylor (Kew). I would particularly like to thank L. Constance (Berkley) for advice and help with the Apiaceae, C. E. Hubbard (Kew) for the grasses and E. V. Watson (Reading) for the mosses. Special thanks are due to Anni Küpfer who has done the administrative work and the greater part of the typing; last minute typing was kindly undertaken by Luise Engler. I would also like to thank Julian Rzoska (IBP, London) who has constantly given encouragement and kept a fatherly eye on the project. Finally I would like to thank my wife for putting up with a physically or mentally absent husband.

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*Number 3.98.69.

CONTENTS

INTRODUCTION

Our aim has been to provide a manual for the identification of freshwater macrophytes of the world. The term "freshwater macrophyte" is to be interpreted as all Charophyta (Stoneworts), Bryophyta (Mosses and Liverworts), Pteridophyta (Ferns and Fern Allies) and Spermatophyta (Seed-bearing Plants) whose photosynthetically active parts are permanently or, at least, for several months each year submerged in freshwater or floating on the water surface. Marine and exclusively brackish water plants have been excluded.

We hope that all macrophytes encountered growing in permanent or seasonally semipermanent water have been included in this book. However, following the above definition means that the majority of plants described are not obligately submerged aquatics. Many plants (for example *Marsilea, Boisduvalia, Eryngium, Thorella, Dopatrium, Glossostigma, Microcarpaea*, etc.) reach sexual maturity only when the habitat has dried out but they are, nevertheless, normally submerged during their juvenile phases of growth. There are many plants, particularly in the tropics, that grow on rocks or trees by streams, rivers and waterfalls. After rain they may be submerged in swiftly flowing water, sometimes for only a few hours at a time. These plants are called rheophytes and, although specialised for this particular kind of habitat, they have been excluded from this book because their vegetative growth and reproduction takes place in the terrestrial milieu. In the colder regions of the world and on high mountains many normally terrestrial plants may be found growing submerged in water; on the whole these plants have been excluded.

Two large general identification keys are presented. The first (page 6), is a more or less traditional key to families based on reproductive structures. The second (page 16), is a key to genera and other higher taxonomic categories based, as far as possible, on easily seen vegetative characters. The non-specialist is recommended to use the second key. With the exception of monotypic families, further keys to each genus are provided after the family description. From the point of view of keys the Bryophyta are treated as a single family. The genera within each family and the families within each higher taxonomic category (Charophyta, Bryophyta, Pteridophyta and Spermatophyta) are arranged alphabetically.

Botanical nomenclature is unfortunately still somewhat unstable so the commonest synonyms are cited in square brackets after the accepted name. Frequently the name in square brackets is not a synonym in a strictly nomenclatural sense. It is often the case that the cited synonym is a perfectly valid genus but the aquatic species have been removed from it. This kind of synonym is followed by "pro parte" which indicates that this name is only a synonym from the point of view of the aquatic species. For example,

Hydropectis [*Pectis* pro parte] indicates that the aquatic species has been taken out of the genus *Pectis* and placed in *Hydropectis,* the other species of *Pectis* are terrestrial plants. The folly of citing local names was realised at an early stage in the preparation of this book. For example, the name "pyle" is used by some people to refer to either *Salvinia* or *Pistia* or *Eichhornia* and by other people to all or some of them collectively. We have therefore given scientific names only and beg the users of this book to adopt them.

The family and generic descriptions are intended to be diagnostic and refer, as a rule, only to the aquatic members. As far as possible, the generic descriptions have been based on living or pressed plant specimens and care has been taken to describe the juvenile and sterile submerged parts. We have tried to keep the botanical terminology down to a minimum. A glossary is provided on page 551.

The illustrations have been based, where possible, on living or dried plant material. Like the descriptions the illustrations are intended to be diagnostic. For each genus we have chosen one or occasionally two representative species that show the important features for the identification of the genus as a whole. Time, printing space and expense have prevented us making full comprehensive drawings of each species. The length of the scale line accompanying each drawing is given in brackets in the legend.

It is often thought that the simplest way to identify a plant is to examine a set of pictures until one is found that resembles it. This method becomes impractical when many plants are involved. Moreover, many aquatic plants are superficially alike (natural selection is a strong mistress) and even if the pictures show the difference the user must be directed by keys and descriptions as to what points to observe.

To keep the size of this book within reasonable limits we have had to make a compromise with the references. On page 4 a selected bibliography of the larger works of general value to the taxonomy of aquatic plants is given. The references following each family or generic description have been carefully chosen to serve as an introduction to the taxonomic literature of the group in question. Occasionally the reference chosen is of limited value in itself but may include a full bibliography. The references cited in this book should therefore be considered as no more than a guide to the literature on aquatic plants. However, as a particularly valuable source book we would like to single out Sculthorpe, C. D. The biology of aquatic vascular plants. London (1967).

The observations following the generic descriptions give information on the number of species, geographical distribution, the kinds of habitats where the plants grow and notes on economic importance. If any species are known to be weeds or pests this is mentioned. However, when undesirable qualities of a species are described it does not mean that this species must always be considered a pest. A weed is best defined as a plant that grows where it is not wanted. In some man-made or artificially maintained waters a particular plant species may be regarded as a pest but in other, often natural, waters the same species may be highly desirable. For example, *Typha* (Reedmace) a widespread and common reedswamp plant is very important as a shelter and food plant

for a wide variety of animals, it also collects silt and is very valuable in stabilizing the banks of rivers and lakes and thus prevents flooding. However, *Typha* in a man-made irrigation ditch is far from desirable as it reduces water-flow and its silt collecting properties may eventually cause flooding. Another example is *Eichhornia crassipes* (Water Hyacinth); it is without doubt a disaster on the River Nile in the Sudan but in some regions of S.E. Asia it is considered desirable and is even cultivated as pig and fish food.

While we hope that this manual will prove useful, we are fully aware that it has many deficiencies and will doubtless be found to contain errors. We would be most grateful if users of the book who detect errors or omissions would inform us.

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KEY TO FAMILIES AND OTHER MAJOR GROUPS BASED ON REPRODUCTIVE ORGANS

A key to families and genera based on vegetative structures is to be found on page 16.

The numbers following the plant names refer to the page numbers in the text.

1A Egg cell surrounded by 5, elongate spirally wound cells; internodes with 1, elongate, axial cell

Characeae p. 40

1B Egg cell surrounded by a multicellular jacket or tissue; internodes multicellular

2A Sporophyte parasitic on gametophyte (mosses)

Bryophyta p. 47

2B Sporophyte not parasitic on gametophyte

3A Sporophytes reproducing by spores which give rise to small gametophytes (ferns)

4A Sporangia embedded on the adaxial leaf surface near the base

Isoetaceae p. 84

4B Sporangia not embedded in the leaf, borne either adaxially on peltate scales, abaxially on leaf surface, or in hardened nut like structures

5A Sporangia borne adaxially on peltate scales; stems grooved and jointed

Equisetaceae p. 85

5B Sporangia not borne adaxially on peltate scales; stems not grooved, not jointed

6A Sporangia borne on the abaxial surface of the leaf; leaves pinnately divided

Parkeriaceae p. 90

6B Sporangia borne in hardened, nut-like structures; leaves simple or with 2 or 4 leaflets

7A Plants free-floating

8A Leaves opposite; abaxial leaf surface hairy

Salviniaceae p. 93

8B Leaves alternate; abaxial leaf surface glabrous

Azollaceae p. 87

7B Plants not free-floating; with elongate creeping stems and erect or floating leaves

Marsileaceae p. 88

3B Sporophytes reproducing by seeds (flowering plants)

9A Plants not clearly differentiated into stem with leaves
10A Plants not attached to a solid substrate

Lemnaceae p. 286

10B Plants firmly attached to a solid and hard substrate by a band-, disc- or irregularly-shaped thallus (usually in swiftly flowing water)
11A Flowers bisexual; sepals 2, or more (widespread. mostly tropical)

Podostemaceae p. 445

11B Flowers unisexual, sepals absent (Madagascar and S. Africa)

Hydrostachyaceae p. 270

9B Plants clearly differentiated into stem with leaves
12A Petals present (see p. 12)
13A Carpels embedded in the flat top of the fleshy receptacle (herbs with large, erect, peltate leaves)

Nelumbonaceae p. 332

13B Carpels not embedded in the flat top of the fleshy receptacle or receptacle not fleshy
14A Sepals sepaloid and petals petaloid (perianth clearly differentiated into petals and sepals, see p. 11)
15A Petals free (see p. 9)
16A Ovary superior (see p. 9)
17A Ovaries and styles 2 or more, free, or united only at base of ovary
18A Leaves in opposite pairs, simple, entire linear to ovate; plant fleshy

Crassulaceae p. 184

18B Leaves alternate or divided or lobed
19A Sepals 5 or occasionally more

Ranunculaceae p. 502

19B Sepals 3
20A Plant with milky latex; seeds scattered on inner walls of ovary

Limnocharitaceae p. 297

20B Plant without milky latex; seeds solitary or a few on an axillary placenta

Alismataceae p. 99

17B Ovaries and styles united, or carpels solitary

21A Petals 3, or inner perianth 3, petal-like
22A Flowers in a more or less globose head, subtended by an involucre of bracts; outer perianth segments scarious
23A Flowers unisexual; inner perianth segments inconspicuous
Eriocaulaceae p. 233
23B Flowers bisexual; inner perianth segments conspicuous and showy
Xyridaceae p. 543
22B Flowers not in a globose head, not subtended by an involucre of bracts; outer perianth segments not scarious
24A Pedicels subtended by a lanceolate bract
25A Leaves linear, notched at apices, not enclosing the stem at bases
Mayacaceae p. 321
25B Leaves lanceolate to ovate, entire at apices, enclosing the stem at bases
Commelinaceae p. 180
24B Pedicels not subtended by a lanceolate bract
26A Flowers in spikes; fruit a nut
Polygonaceae p. 481
26B Flowers solitary or clustered in leaf axils; fruit a capsule
Elatinaceae p. 231
21B Petals more than 3
27A Stamens more than 2 times as many as petals
28A Leaves with long petioles; stigmas radiate
Nymphaeaceae p. 334
28B Leaves sessile; stigmas capitate
Clusiaceae p. 179
27B Stamens 2 times as many as petals or fewer
29A Petals unequal in shape and size
30A Leaves compound (1- or 2-pinnate); fruit a pod
Fabaceae p. 242
30B Leaves simple; fruit a capsule
Balsaminaceae p. 161
29B Petals more or less equal in shape and size
31A Flowers unisexual
Euphorbiaceae p. 239
31B Flowers bisexual
32A Leaves with traps and terminal bristles; plants free-floating
Droseraceae p. 229
32B Leaves without traps and without terminal bristles; plants bottom rooted
33A Anthers opening by terminal pores; stamens distinctly jointed
Melastomaceae p. 323

33B Anthers opening by longitudinal slits; stamens straight

34A Fruit a 3-angled nut

Polygonaceae p. 481

34B Fruit a capsule

35A Petals and stamens inserted on the sepal tube

Lythraceae p. 310

35B Petals and stamens inserted on the receptacle; sepals not tubular

36A Flowers sessile or shortly stalked, solitary or in clusters in leaf axils

Elatinaceae p. 231

36B Flowers distinctly stalked, in terminal racemes

Brassicaceae p. 163

16B Ovary inferior or semi-inferior

37A Petals 3

Hydrocharitaceae p. 254

37B Petals more than 3

38A Petals numerous, usually more than 8

Nymphaeaceae p. 334

38B Petals usually 4 or 6

39A Fruit a capsule

Onagraceae p. 343

39B Fruit indehiscent, nut-like or a schizocarp

40A Leaves often with swollen, floating petioles; fruit with 2 or 4 thorn-like processes

Trapaceae p. 537

40B Leaves without swollen, floating petioles; fruit without thorn-like processes

41A Flowers in an umbel or head

Apiaceae p. 117

41B Flowers axillary or in racemes or spikes

Haloragaceae p. 246

15B Petals united

42A Ovary superior

43A Flowers in a globose head subtended by an involucre of bracts; perianth 3-merous

Eriocaulaceae p. 233

43B Flowers not in a globose head not subtended by an involucre of bracts; perianth 4- or 5-merous

44A Flowers actinomorphic (radially symmetrical)

45A Stamens opposite the petals; placentation free-central

46A Sepals 2, usually free
Portulacaceae p. 493

46B Sepals 5, united into a tube below
Primulaceae p. 497

45B Stamens opposite the sepals, or more than petal lobes; placentation not free-central

47A Ovary 3-locular
Polemoniaceae p. 480

47B Ovary 2- or rarely 4-locular

48A Placentation parietal; petals usually with hairs or lamellae on the surface
Menyanthaceae p. 326

48B Placentation axile; petals usually glabrous and smooth

49A Fruit of 4, united nutlets; style gynobasic (minute herbs)
Tetrachondraceae p. 535

49B Fruit a capsule; style terminal

50A Ovules 1 or 2 in each loculus; petal tube funnel-shaped
Convolvulaceae p. 182

50B Ovules many; petal tube lobed

51A Styles 2, united only at base
Hydrophyllaceae p. 269

51B Style 1, sometimes 2-lobed at apex
Scrophulariaceae p. 511

44B Flowers zygomorphic (bilaterally symmetrical)

52A Plant bearing bladder-like traps
Lentibulariaceae p. 292

52B Plant not bearing bladder-like traps

53A Fruit of 4 nutlets; style gynobasic
Lamiaceae p. 280

53B Fruit a capsule; style terminal

54A Seeds on papilliform or hook-like projections
Acanthaceae p. 95

54B Seeds borne directly on the placenta
Scrophulariaceae p. 511

42B Ovary inferior or semi-inferior

55A Petals 3; some stamens sterile and petaloid

56A Ovary 1-locular; 2 anther loculi fertile
Marantaceae p. 317

56B Ovary 3-locular; 1 anther loculus fertile
Cannaceae p. 172

55B Petals 4 or more; stamens not petaloid
57A Inflorescence a head subtended by an involucre of bracts
Asteraceae p. 155
57B Inflorescence a spike or panicle or flowers solitary
58A Leaves opposite or apparently whorled
59A Flowers in branched cymes; lower leaves whorled
Rubiaceae p. 505
59B Flowers solitary in leaf axils; lower leaves in opposite pairs
Trapellaceae p. 539
58B Leaves alternate or all basal
60A Inflorescence densely spicate, terminal
Sphenocleaceae p. 533
60B Inflorescence lax or flowers axillary
61A Flowers actinomorphic; anthers free
Primulaceae p. 497
61B Flowers zygomorphic; anthers united
Lobeliaceae p. 302
14B Sepals and petals petaloid (perianth not clearly differentiated into sepals and petals)
62A Perianth segments free; ovary always superior
63A Fruit a solitary, 3-sided nutlet
Polygonaceae p. 481
63B Fruit of several carpels or a dehiscent capsule
64A Flowers in simple or forked spikes
Aponogetonaceae p. 135
64B Flowers solitary, or in variously pedicellate inflorescences
65A Flowers zygomorphic; stamen 1
Philydraceae p. 346
65B Flowers actinomorphic; stamens more than 1
66A Inflorescence umbel-like; leaves linear, arising in 2 rows from a rhizome
Butomaceae p. 166
66B Inflorescence not umbel-like; leaves not linear, not in 2 rows
67A Carpels united; stigma radiate
Nymphaeaceae p. 334
67B Carpels free; stigma not radiate
68A Leaves sheathing at base, never peltate, never divided into capillary segments
Ranunculaceae p. 502
68B Leaves not sheathing at base, peltate or divided into capillary segments
Cabombaceae p. 168

62B Perianth segments united; ovary inferior or superior
69A Ovary superior
70A Inflorescence subtended by 2 spathes; style 1; leaves parallel nerved
Pontederiaceae p. 482
70B Inflorescence not subtended by spathes; styles 2 or 3; leaves with midrib and lateral, pinnate nerves
Polygonaceae p. 481
69B Ovary inferior
71A Fruit a 2-seeded schizocarp
Apiaceae p. 117
71B Fruit a capsule
72A Inner and outer perianth whorls dissimilar in shape
Iridaceae p. 273
72B Inner and outer perianth whorls similar
73A Perianth segments united for at least half their length, forming a tube below; style long
Amaryllidaceae p. 115
73B Perianth segments united only at base; style short
Hypoxidaceae p. 271
12B Petals absent
74A Perianth sepaloid, scarious or membranous (see p. 14)
75A Perianth sepaloid (not scarious or membranous, see p. 13)
76A Flowers crowded on to a fleshy spike (spadix) subtended by a fleshy bract (spathe)
Araceae p. 137
76B Flowers not crowded on to a spadix subtended by a fleshy spathe
77A Ovary superior
78A Fruit a many seeded capsule or of many seeded carpels
79A Sepals united into a tube
Lythraceae p. 310
79B Sepals free
80A Stamens 15, dimorphic
Nymphaeaceae p. 334
80B Stamens 6, monomorphic
Brassicaceae p. 163
78B Fruit a 1-seeded capsule or indehiscent
81A Flowers solitary, sessile in the axils of whorled, forked capillary leaves
Ceratophyllaceae p. 177
81B Flowers in spikes or stalked; leaves entire