ECOLOGY OF HALOPHYTES

edited by
ROBERT J. REIMOLD
WILLIAM H. QUEEN

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PREFACE

This publication arose as a result of a symposium on the ecology of halophytes sponsored by the Physiological Ecology section of the Ecological Society of America and held as a portion of the American Institute of Biological Sciences meetings, August 1972. The interest generated in preparing and presenting this symposium all pointed to the need for a review volume on the salt marsh ecosystem, the saline soil ecosystem, and what was known about these systems. The diversity of interests of the contributors demonstrates the comprehensive nature of the *Ecology of Halophytes.*

The *Ecology of Halophytes* considers the fundamentals of distribution, anatomy, and physiology of halophytes. It also provides an overview of the role of the halophyte in ecosystems in various parts of the world. A section on habitat associations of halophytes considers the relation of the plants to other fauna and flora in natural systems. A final section deals with recent applied research related to halophytes and quantification of the impact of man on the ecology of halophytes.

It is hoped that this publication will be of use for various disciplines working in saline wetlands ecosystems. It is intended to serve land use planners, federal and state natural resources and transportation interests, and real estate developers in providing a comprehensive summary of the "state of the art" in understanding halophytic ecosystems. With a better fundamental knowledge of the system, the above mentioned professionals should be better able to plan activities and uses compatible with the natural halophytic ecosystem and hopefully avoid some of the past errors man has made.

We acknowledge the assistance of Charles R. Malone, program chairman for the Ecological Society of America, and F. John Vernberg, chairman of the Physiological Ecology Section of ESA, for arranging the symposium. Thanks also go to Winona B. Vernberg, Lee N. Miller, and James G. Gosselink for their assistance as symposium session chairman.

We extend our sincere appreciation to the many scientists who have served as editorial reviewers for each chapter. In particular we recognize the valuable assistance of Rick A. Linthurst for his dedicated efforts of manuscript, proof and camera ready copy production. The untiring motivation from our families is also acknowledged.

Robert J. Reimold
William H. Queen

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FOREWORD

Salt marshes are many things to many men. To those who live on the east coast they are the one remaining accessible bit of undisturbed wilderness. Unfortunately as unoccupied space they offer great opportunity to those who would destroy them by development. On the other hand, being the favored habitat of water fowl, substantial areas of marshland are being set aside as wildlife reservations which require understanding of their ecology for their maintenance.

To the scientist salt marshes provide for study an ecological system with well-defined boundary conditions within which physical and biological factors interact. The physical environment is hostile to most of the organisms of the land, of the fresh water wetlands, and of the open sea. The result is a biota limited to the relatively few species of plants and animals adapted to periodic inundation and to life in waters of varied salinity.

The salt marshes have been formed in sheltered places by waterborne sediments collected by those halophytes which can populate the intertidal zone. Of these *Spartina alterniflora* is the principal species throughout its range because it can survive longer periods of submergence than others and hence occupy the foreshore at lower tide levels. The marshes, as we know them today, have developed during a period of rising sea level. The peats formed each year have buried and often left undisturbed those formed in earlier years. A record is preserved in the depths of the peat deposits from which the history of the marsh may be reconstructed and which provides a chronology of the recent rise in sea level. Also preserved are artifacts which give evidence of man's occupation of marshland areas and of his culture during earlier times.

The interaction of tidal flow, the resulting sedimentation and erosion, and the physiology of the halophytes has produced a unique land form for the attention of the geomorphologist. The creeks which drain the marshes have an hydrology which differs in important respects from terrestrial streams. The soil of the marshlands is distinctive in its saline character, its prevalent saturation with water, its high organic content, and its proverty in oxygen.

In the study of salt marshes, the botanists have done a more thorough job than others. In the present volume they have continued to lead the way by the investigation of the halophytes and their ecology. The collection of papers presented should be useful to those with diverse interests as an account of what is being done currently toward understanding the ecology of the marshes.

Alfred C. Redfield
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PART I. HALOPHYTES: AN OVERVIEW

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SALT MARSHES AND SALT DESERTS OF THE WORLD

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Introduction

In this contribution I do not intend to say anything about the physiology and morphology of salt marsh plants, nor anything about salt marsh soils and animals because these topics are covered in other articles in this volume. Since many of you are familiar with my book on salt marshes and salt deserts of the world, I will consider intensively only those areas in which additional information has come to hand since the book was written.

In the past there has been considerable debate over what are halophytes. Generally, species capable of tolerating 0.5% or more NaCl are regarded as halophytes. Some evidence has been published in the past to indicate that some species. are obligate halophytes and reach their optimum growth at moderate to high salinities. Barbour (1970) has discussed this aspect in some detail and concluded that very few species are restricted above 0.5% NaCl.

One characteristic of salt marshes and salt deserts is provided by the fact that only a relatively small number of plant species are capable of tolerating the degrees of salinity that occur. As a result, there are broad geographical areas in which there is a substantial uniformity in the vegetation. In some cases, subdivision can be based on temperatures or upon soil type. With this as background it seems to me that the major groups of maritime salt marshes and salt deserts (Fig. 1) are as follows:

Maritime Marshes

Arctic Group

The Arctic Group is represented by the salt marshes of the Canadian and American Arctic, Greenland, Iceland, northernmost Scandinavia, and arctic Russia. The environment is extreme, especially in winter, and the marshes appear to be somewhat fragmentary as a result. Succession is very simple. The vegetation is dominated by the grass *Puccinellia phryganodes*, though species of *Carex*, especially *C. subspathacea* and *C. maritima*, play an important part at higher levels.

Northern European Group

This group includes marshes from the Iberian Peninsula northward around the English Channel, North Sea Coasts, and the Baltic Sea, as well as those on

Fig. 1.
World distribution of salt-marshes, salt deserts (solid black) and mangrove swamps (latched)

the Atlantic coasts of Eire and Great Britain. Whilst there is a fundamental similarity in physiognomy and floristic composition, nevertheless, different communities can be recognized in specific areas. These sub-areas are related either to soil differences or, in the case of the Baltic, to salinity differences. Throughout the region there is a dominance of annual *Salicornia* species, *Puccinellia maritima*, *Juncus gerardi*, and the general salt marsh community. The North European Group can be divided into the following five subgroups:

Scandinavian Subgroup – Scandinavian marshes are characterized by a high proportion of sand in the soil and have developed on a rising coastline where newly exposed shore sand can be blown inland. They are found in Scandinavia, Schleswig-Holstein, the west coast of Britain from the Severn to Northern Scotland, on the east coast of Eire, and from Kincardine to Inverness on the east coast of Scotland. These marshes are dominated by grasses, especially *Puccinellia maritima*, *Festuca rubra*, and *Agrostis stolonifera*, and for this reason are grazed by domestic animals. Grazing probably results in the elimination, or control, of dicotylodonous herbs such as *Aster*, *Limonium*, *Triglochin*, etc. Since the publication of *Salt Marshes and Salt Deserts of the World* a number of contributions have been made to the literature of the Scandinavian Subgroup. Foremost among these have been the papers by Dalby (1970), South Wales marshes; Gillner (1960), Swedish marshes; Gimingham (1964), East Scottish marshes; Packham and Liddle (1970), West Wales marshes; Round (1960), Dee marshes; and Taylor and Burrows (1968), Dee marshes.

North Sea Subgroup – North Sea marshes have much more clay and silt in the soil and there tends to be a wider range of communities. Grasses are not so dominant and the general salt marsh community plays a greater role in the successions. These marshes are generally associated with a subsiding coastline, but their character is currently changing through the introduction or natural spread of *Spartina townsendii* or *S. anglica*. North Sea marshes are represented by the marshes of eastern England, southeast Scotland, northern Germany, and the low countries. Recent significant publications on the marshes of the North Sea Subgroup have been those by Koster (1961) and Beeftink (1965, 1966).

Baltic Subgroup – The Baltic Subgroup differs from the Scandinavian and North Sea Subgroups by the presence of some species, e.g. *Carex paleacea*, *Juncus bufonius*, and *Desmoschoenus bottnica*, that occupy dominant places in the succession. The brackish nature of the Baltic also permits *Scirpus* to be the primary colonist.

English Channel Subgroup – Marshes in this subgroup were probably comparable with the North Sea Subgroup, but since the appearance of *Spartina townsendii* and *S. anglica* towards the end of the last century and their subsequent spread, these marshes physiognomically now look more like those of the U.S.A. In Poole Harbour, the origianl home of *S. townsendii*, aerial photography has been employed to see whether there have been any recent changes in the vegetation (Ranwell et al. 1964, Bird and Ranwell

1964). The Total area of *Spartina* has not altered materially though there has been some seaward spread of *Scirpus* (2 ft. per annum), *Glaux*, *Phragmites* (4 ft. per annum), *Puccinellia*, and *Aster tripolium*.

Southwest Eire Subgroup – This subgroup is still regarded as a separate entity because of the peaty nature of the soil and the simplicity of the succession. It is a group that requires further study.

Mediterranean Group

Whilst Mediterranean marshes show some affinity with those of northern Europe, there are species, e.g. of *Arthrocnemum* and *Limonium*, which are characteristic. The eco-climax is dominated by *Juncus acutus* and the Mediterranean is the only region where this species attains such prominence. It is perhaps convenient to recognize western and eastern subgroups though obviously there is a gradual transition from one to the other. The marshes of the Caspian would appear to belong to a separate subgroup.

Western Mediterranean Subgroup – The marshes of southern France, particularly of the Rhone Delta (Knierr 1960, Corre 1962, Molinier et al. 1964) are typical of this subgroup. The primary colonists are *Salicornia herbacea* agg. or *Salsola soda* plus *Suaeda* or a *Kochio-Suaedetum. Salicornia fruticosa* is also prominent. Other characteristic communities are the Limonieto-Artemisietum, Limonieto-Limoniastretum, Crithmo-Staticetum, and Halimionetum portulacoidis.

Eastern Mediterranean Subgroup – Whilst many of the dominants are the same as in the western subregion, there are eastern species present, such as *Halocnemum strobilaceum*, *Petrosimonia crassiflora*, *Bupleurum gracile*, and *Suaeda altissima*.

Caspian Salt Marshes – Annual *Salicornia* or *Halocnemum* (Tagunova 1960) is the primary colonist of the Caspian marshes with thickets of *Salsola sola*, *Suaeda*, or *Puccinellia gigantea* behind (Agadzhanoz 1962). *Kalidium caspicum* and *Anabasis aphulla* are other typical species.

Western Atlantic Group

Marshes in this group extend from the St. Lawrence down to Florida where there is a transition to mangrove. They are subdivided essentially on differences in mode of formation, though there are floristic differences as well in respect to the southern subregion. The halophyte flora of the Atlantic coast of North America is discussed in detail by Duncan in another article of this volume.

Bay of Fundy Subgroup – This subgroup is characterized by the significant role of *Puccinellia americana*, and *Juncus balticus* var. *littoralis* at the highest levels, and by a transition to bog rather than fresh-water swamp. These marshes are formed in front of a weak rock upland.

New England Subgroup – New England marshes are formed in front of a hard rock upland, and the soil is a peat rather than a muddy clay, as in the other two subgroups. *Puccinellia americana* is not a dominant, and the transition is to reed swamp.

Coastal Plain Subgroup – Recent descriptions of coastal plain marshes have been given by Adams (1963) and Davis and Gray (1966), whilst Blum (1963, 1968) has described the algal communities. The marshes have developed in front of a soft rock upland.

Pacific American Group

The marsh communities of the American Pacific Coast are entirely different from those elsewhere and the successions appear to be very simple. The marshes extend from California to southern Alaska. They are discussed by MacDonald and Barbour in another paper in this volume.

Sino-Japanese Group

Recent accounts (Ito 1961, 1963; Ito and Leu 1962; Umezugi 1964; Miyawaki and Ohba 1965) have added much valuable information about this region. Primary communities are dominated by *Triglochin maritima*, *Salicornia brachystachya*, or *Limonium japonicum*, though in the far north *Suaeda japonica* with *Atriplex gmelini* occupy this position with *Limonium tetragonum* behind. Southwards the equivalent zone is occupied by *Zoysia macrostachya* or *Puccinellia kurilensis*. In the northern part a relationship to the arctic region is evidenced by the presence of *Carex ramenskii*. It is probable that this region should be subdivided into northern and southern subgroups.

Australasian Group

The Australasian Group is characterized by some specifically southern hemisphere species such as *Salicornia australis*, *Suaeda nova-zelandiae*, *Triglochin striata*, *Samolus repens*, and *Arthrocnemum* species. Some recent descriptions are those by Sauer (1965) and Clarke and Hannon (1967). Floristic similarities justify regarding them as one region, but there are sufficient floral differences to render it desirable to subdivide the group.

Australian Subgroup – This subgroup is characterized by *Arthrocnemum arbuscula*, *A. halocnemoides*, *Hemichroa pentandra*, and *Suaeda australis*. At higher levels *Atriplex paludosa*, *Limonium australis*, and *Frankenia pauciflora* are important.

New Zealand Subgroup – Nearly all species of the New Zealand subgroup are found on Australian salt marshes with the exception of those listed above.

South American Group

This group is characterized by species of *Spartina* (*S. brasiliensis*, *S. montevidensis*), *Distichlis*, *Heterostachys*, and *Allenrolfea* which are not found elsewhere. These marshes are in need of further study.

Tropical Group

Tropical marshes generally occur at high levels behind mangrove swamps and are flooded only by extreme tides. Typical species are *Sesuvium portulacastrum* and *Batis maritima.*

Inland Marshes and Alkali Regions

Inland European Group

Whilst there is a general similarity throughout, biogeographically this group seems subdivisible into northern and southeastern subgroups.

Northern European Subgroup – Floristically the marshes in this subgroup are closely related to the northern European maritime marshes. They possess the coastal species *Salicornia* and *Plantago maritima*, whilst *Puccinellia distans* and *Halimione pedunculata* are characteristic species.

Southeastern European Subgroup – These marshes contain both northern and eastern species. In Italy, *Crypsis aculeata* and *Aster tripolium* var. *pannoricus* are of eastern affinities. A clearer picture of this vegetation is found in recent accounts by Bodrogkozy (1965, 1966). Species that could be regarded as representative of this subgroup include the two above together with *Cyperus pannonicus, Puccinellia limosa, Lepidium cartilagineum, Frankenia* spp,. *Halimione verrucifera, Salsola soda*, and *Suaeda splendens.*

Inland Asian Group

It would appear that this group can be subdivided into at least three subgroups. There may prove to be more, and one or more may need elevation to group status.

Aralo-Caspian Subgroup – Within this subgroup there may be three minor regions, namely, Aralo-Caspian, Turkestan, and Trans-caucasian. Birand (1960), Kutnetsov (1960), Rusyaeva (1961), Rustamov (1962), Vinogradov (1960), and Momotov (1963), among others, have provided valuable accounts. Whilst there are floristic affinities with the Southeastern European area, there are species such as *Kalidium foliatum, K. caspicum, Halostachys caspia*, and *Halocnemum crassifolia* that are typical of these salt deserts.

Irak-Central Asian Subgroup – This subgroup has affinities with the North African Subgroup (see below), but there are some characteristic species such as *Suaeda vermiculata, S. palestina, Seidlitzia rosmarinus*, and *Anabasis articulata.* For a recent general account, see papers by Zohary (1963) and Habib et al. (1971).

East Asian Subgroup – The information on this subgroup is very scanty but it seems to be characterized by species of *Atriplex* and *Artemisia.*

African Group

The African Group is conveniently divided into northern, eastern, and southwestern subgroups though further subdivisions may be desirable.

North African Subgroup – Apart from widespread species, this subgroup contains western species in the Moroccan area, and there is a gradual infiltration of eastern species as one travels towards Palestine. The most widespread community is dominated by *Salicornia fruticosa* and *Sphenopus divaricatus.* Other typical species include *Arthrocnemum glaucum, A. macrostachya*, and *Suaeda fruticosa.*

Southwest African Subgroup – This subgroup is found around the shores of saline lakes. *Scirpus robustus* and *S. spicatus* are primary colonists.

East African Subgroup – Whilst the East African Subgroup has some affinities with the North African Subgroup (e.g. *Arthrocnemum glaucum*), there are some typical species, e.g. *Halopeplis perfoliata* and *Aeluropus lagopoides.*

North American Group

Whilst some species of the North American Group are found also in salt marshes of either the Pacific or Atlantic coasts (Branson 1967), there are other species, such as *Salicornia utahensis, Allenrolfea occidentalis, Sarcobatis vermiculata*, and *Atriplex confertifolia* that are characteristic of the group. Arising from recent contributions (Dodd et al. 1964; Dodd and Coupland 1966; Hunt and Durrell 1966; Branson, Miller, and McQueen 1967; Cusick 1970; Ungar 1965, 1967, 1968, 1970; Ungar et al. 1969; Bradley 1970) it seems that the region can be subdivided into two subgroups.

North Western Subgroup – This subgroup is characterized by the presence of *Salicornia rubra* and *Puccinellia nuttallii.*

South Western Subgroup – This subgroup is characterized by *Sporobolus airoides* and *Tamarix pentandra.*

South American Group

Characteristic species of the inland saline areas of the South American Group are *Heterostachys ritteriana, Allenrolfea patagonica, Spartina montevidensis*, and *Salicornia gaudichaudiana.*

Australian Group

This Australian Group is mainly characterized by species of *Atriplex* and *Arthrocnemum halocnemoides.*

Discussion

The dominant vegetation of maritime salt marshes is essentially phanerogamic herbs, though some shrubs also occur. Inland salt marshes, and especially salt deserts, are typified by shrubs. Apart from the phanerogams, maritime salt marshes also carry an extensive algal vegetation which may, in places, be as important as the phanerogams. This is particularly the case where salt marsh fucoids are concerned (European and U.S.A. Atlantic marshes). As may be expected, Cyanophyceae are abundant and they can occur also on the soils of inland areas. There are also characteristic members of the Rhodophyceae, especially *Catenella* and *Bostrychia*, which are to be found at the base of plants at the higher levels. These two genera are interesting because they occupy a rather similar niche in mangrove swamps on pneumatophores and trunk bases. Chlorophyceae are ubiquitous, especially species of *Lola*, *Rhizoclonium*, *Chaetomorpha*, *Ulothrix*, and *Enteromorpha*. Species of the Xanthophycean *Vaucheria* are not uncommon as pioneers (Nienhuis and Simons 1971), especially on the mud banks of creeks.

On maritime salt marshes, continual accumulation of silt steadily raises the soil level. This reduces the number of inundations which has an effect on the soil salinity. The overall result is successive changes in vegetation giving rise to a succession. Provided the land/sea level remains constant, vertical growth of a marsh will cease and the final vegetation is regarded as the sere climax. In the past, some interest has centered around the time taken to develop to the sere climax from the arrival of the first colonists. Apart from the evidence that can be obtained from old maps, calculations can also be based upon experimentally determined accretion rates coupled with mean vertical height determinations of the various stages in the succession. More recently radioactive carbon techniques have also been employed (Lyon and Harrison 1960, Redfield and Rubin 1962, Sears 1963, Bloom and Ellis 1965, Bloom 1967), especially with respect to the New England (U.S.A.) marshes. This is currently the most accurate method, and has resulted in amendments to rates determined earlier by the older methods. Some of the rates, e.g. those for New Hampshire (3 ft. per century) and Nova Scotia (1.4 - 2 ft. per century), are widely removed from the general rate for that coast of 0.5 ft. per century and further measurements are required. At present it would seem that on this coast it must take about 600-700 years for a marsh to pass through all its phases up to the *Juncus gerardi* zone.

Apart from some of the earlier work on the movement of the water table of salt marshes and the effect of tidal height upon it, no real new information has appeared though Tyler (1971) has provided some data for Baltic Sea meadows. Whilst the existing information has enabled a generalized picture to be established, there may be marshes that do not conform. Early studies by the present author led to the hypothesis that on maritime salt marshes the water table never rises completely to the surface, even during flooding tides, so that an aerated layer existed in which most of the roots of salt marsh plants are to be found. The earlier work has been extended by the studies of Teal and Kanwisher (1961) on Georgia marshes and by Clarke and Hannon (1969) on Australian marshes. The former author found that only the upper few centimetres contained any oxygen and that, in general, reduction intensity was high except in well-drained areas. In Great Britain, 'die-back' in *Spartina townsendii* has been related to a toxic reduced inorganic ion - possibly sulphide - in the soil (Goodman and Williams 1961). These sulphides must lower the soil oxygen content, but how the oxygen deficiency operates upon the plant's metabolism has still to be solved (Lambert 1964). Clarke and Hammon (loc. cit.) in their study of Sydney salt marshes pointed out that the aerated layer is not completely continuous. It is clearly related to soil structure, abundance of crab, worm, and mollusc burrows, and to the existence of old decayed roots.

Critical work has still to be carried out on maritime salt marshes in order to relate their zonation to the zonation characteristic of rocky shores. It would seem that the primary colonists generally occupy the upper part of the eu-littoral belt and that most of the communities are located in the supra-littoral fringe.

The author is still of the opinion that the Montpellier system represents the best phyto-sociological system so far as salt marsh vegetation is concerned. Beeftink (1968) has discussed the classification of European salt marsh communities on this basis but I believe that because of the general uniformity of the vegetation, any such classification should be on a world-wide basis. The major classes and orders would be as follows:

1. Class Zosteretea	Order 1.	Halobenthalia
2. Class Salicornietea	Order 2.	Coeno-Salicornietalia
	Order 3.	Coeno-Puccinellietalia
	Order 4.	Coeno-Spartinetalia
	Order 5.	Limonietalia
	Order 6.	Coeno-Festucetalia
	Order 7.	Halostachyetalia
3. Class Juncetea	Order 8.	Coeno-Juncetalia
4. Class Phragmitetea	Order 9.	Halo-Phragmitetalia
5. Class Caricetea	Order 10.	Halo-Caricetalia

Because of the economic importance attached to *Spartina*, continuing studies of its ecological requirements have proceeded. These are discussed in other articles of this volume. A study of so-called *S. townsendii* has shown that there is the original sterile F_1 hybrid and a subsequent developed fertile autotetraploid (Hubbard 1967; Marchant 1963, 1966, 1967, 1968, 1970). This latter has been termed *S. anglica* (Hubbard 1968). The two species, collectively, occupy a world total of some 70 sq. miles (Ranwell 1967), the fertile hybrid being the more successful (Goodman et al. 1969). Both species have shown themselves to be very successful colonists of mudflats so long as daily tidal submergence is not more than six hours (Hubbard 1965a, b; Chalter 1965; Taylor and Burrows 1968; Lambert 1964; Bascand 1969). Both species appear to require low winter temperatures because neither do well, even in warm temperate areas. In the north island of New Zealand, *S. alterniflora* and *S. gracilis* are both better colonists of mudflats (Bascand 1968, 1970). In places where the plants have become too successful and tend to block channels, control can be achieved by two successive applications of Dalapon (Ranwell and Bowning 1960; Bascand 1968). Hubbard and Ranwell (1966) have reported on the value of cropping *Spartina* marsh for silage. A parasitic pyrenomycete *Haligena spartinae* has been recorded from the species (Jones 1962), but whether this can affect the success of the plant is not known.

It is difficult to determine the extent of inland saline lands because there is no generally accepted criterion as to when a soil is to be regarded as saline. Very considerable areas formerly existed in Eruope [300,000 hectares in Rumania but now reduced by reclamation (Oprea 1965)], particularly in Austria, Hungary, and Bulgaria (Ovdenicharov 1959). At least 75 million hectares or 3.4% of the available land in the U.S.S.R., China, and neighbouring states are saline or alkaline (Boumans and Husbos 1960, Muratova 1959, Agaer 1965). The exact extent is unknown and only a small percentage has so far been put to any use. In India and Pakistan there are about 20 million acres of saline soils (Raheju *in* Bayko 1966), and the same writer reports the development of 300,000 acres in Egypt as a result of irrigation from the Nile bringing the subsurface salts to the surface. The full extent of the vast saline areas on the African continent is just not known. I can find no published data on the area of saline soils in Australia where they are mainly confined to the southern part of the continent. Figures are probably available for Canada and the U.S.A. because Cairns (1969a) has stated that 8-12 million hectares of alkali soils exist in Alberta and Saskatchewan.

With the world at present facing an over population problem and a food shortage, maritime salt marshes and inland salt deserts both represent potential land that could and should be reclaimed for arable purposes. Successful reclamation of these soils is possible and indeed has been carried out in many parts of the world. The method to be used in any one case depends upon an understanding of the base-exchange conditions in the soil, especially that portion of the exchangeable sodium bound to the finer particles (Sambin 1963). Boyko (1966) has pointed out that new views, such as a better understanding of plant reaction to osmotic pressures, and the use of seawater which can be more successful in irrigation than other alkaline waters, especially in promoting increased resistance to drought, give great hopes for further successful reclamation. Raheju (1966) has listed the various reclamation methods used in different countries. It has to be noted that much salinization has arisen as a result of man's disturbance of the ecological balance. We have, however, now become very sensitive to this kind of effect and it should not occur in the future. Most recent reclamation work has centered on 1) the use of gypsum (Sambin 1963; Raikov and Kavadgiev 1965; Ramos et al. 1961; Padhi et al. 1965; Boumans and Ausbos 1960; Agaer 1965; Szabolcs and Abrakham 1964; Prettenhoffer 1964, 1965; Saini 1971) though Szabolcs (1965) found calcium nitrate equally satisfactory; 2) deep ploughing (Cairns 1961, 1969a, 1970; Bowser and Cairns 1967; Cairns and Bowser 1969; Cairns 1971; Prettenhoffer 1964a, 1964b; Zvereva 1960; Bolshakov 1960; Raikov and Kavadgiev 1965; Bodrogkozy 1961-62); and 3) irrigation (Ebert 1971). It is likely, therefore, that economic factors will largely determine the choice of method.

With the reclamation of saline soils, there is also the problem of salt tolerance of crop plants because this determines which crop can first be successfully planted. Most of the recent work here has been summarized by Strogonov (1964) and Boyko (1966).

In conclusion, one may draw attention to the enormous amount of literature that has appeared in the last ten years, and which is indicative of the great importance attached to the reclamation of saline soils. It is inevitable that, as natural phenomena, salt marshes and salt deserts will be greatly reduced in area in future years.

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