Chapter 9
Vegetation of the Aralkum

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9.1 Introduction

The desiccated seafloor of the Aral Sea is called the Aralkum. No terrestrial plants nor their seed banks had been there. But during the last 50 years an intensive invasion by organisms took place and is still taking place. The various vegetation units are described in this chapter. The formation of plant communities, soils, a new groundwater level and aquifers, the processes of ecosystems, are very dynamic. These dynamic succession processes are described in Chap. 10. The dry seafloor is the largest area worldwide where a primary succession is taking place. Unintentionally, mankind has created a huge experiment there.

In 1977 a research programme (by the Geographical Institutes of Moscow) was started in Middle Asia to study the negative effects of the drying process of the Aral Sea and the change in the discharge of the Amu Darya and the Syr Darya. Transects were set up at different coastal areas, stretching from the former coast to the receding coastline. The distribution of the soils and the vegetation was surveyed along these transects. Two of the authors participated in this programme (Wucherer 1979, 1984, 1986, 1990; Dimeyeva 1990; Kabulov 1990; Kurochkina 1979). This programme was stopped in the mid-1980. Presently, the ecological situation on the dry seafloor is different, the diversity of landscapes and plant communities has increased enormously, barchans and mainly salt deserts have spread out on the dry seafloor and salt-dust storms have become a common event.

In 1990 a UNESCO programme started with special emphasis on the delta areas (Geldyeva et al. 2001). The problems of the Aralkum itself had not been addressed since the middle of the 1980. Therefore, a new research programme was started, the international BMBF projects "Succession processes on the desiccated sea floor of the Aral Sea and perspectives of land-use" (1998–2001) and "Combating desertification and rehabilitation of salt deserts in the Aralkum" (2002–2005). These projects aimed to study the ecosystem dynamics in the Aralkum and to test experimental plantings to accelerate the natural colonization by plants. Results on the dynamics of flora and vegetation are given here (see Chaps. 8–10, 15).

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Presently, the dry seafloor of the Aral Sea is a huge salt flat. According to several estimations, it is the source of many million tons of salt and dust blown out by wind annually (Chaps. 5, 7, 16) and transported to rather distant adjacent areas with irrigated fields and settlements. The present and future development is characterised by the creation of salt desert flats.

9.2 Zonal Vegetation and Main Vegetation Types at the Former Coastline

The Aral Sea basin is part of the temperate continental desert and semidesert belt. The area belongs to zonobiomes VIIa and VII (rIII) (Walter 1974; Breckle and Agachanjanz 1994). It is characterized by a zonal mosaic of xerophytic dwarf shrubs on zonal soils (plakor sites) with *Artemisia* species, *Anabasis salsa* and some *Salsola* species. The canopy height is between 20 and 60 cm, the coverage is between 15 and 40% and the amount of phytomass is 8.5 t ha^{-1}. This vegetation type is widespread on the cretaceous and tertiary plateaus (e.g. Ustyurt, Betpak-Dala) and on peneplains adjacent to the mountains.

The parent rocks are often rich in gypsum or salt. Typical soils are burozems (burye), sero-burozems (sero-burye) und serozems. The zonal vegetation at the northern and western coasts of the Aral Sea is often rich in *Artemisia terrae-albae* and *Anabasis salsa* plant communities, rather often intermixed with steppe elements such as *Stipa sareptana* and *Stipa richterana* (at the northern coast).

The psammobiome, a typical sandy desert with rather many plant species, is forming the euxerophytic and mesoxerophytic shrubby and semishrubby vegetation on sand. The appearance of this sand desert is dominated by the rather high growing *Haloxylon* and *Salsola* species (Chenopodiaceae), by *Calligonum* species (Polygonaceae) and by some species from Fabaceae and Poaceae. The main canopy height is between 0.5 and 2.5 m, with a coverage of 20–60%. Soil horizons are not developed, except for a thin layer of a microbiotic crust on the sandy surface forming nonmobile sand, as in many other sand deserts in the world (Breckle et al. 2008). The ongoing wind erosion causes a complicated relief. At the north-eastern coast, between Aralsk and the Syr Darya delta, we have the so-called sand desert Priaralski Karakum. Here, the vegetation is dominated by *Krascheninnikovia ceratoides*, *Calligonum aphyllum*, *Agropyron fragile*, *Artemisia terrae-albae*, *Artemisia arenaria* and several ephemeral species (*Gagea*, *Iris*, *Tulipa*, *Allium*, etc.). At the southeastern coast, typical sand deserts with saxaul plant communities (*Haloxylon persicum* and *Haloxylon aphyllum*) prevail.

The halophytic plant communities are formed by euhalophytic and hemi-halophytic vegetation on saline soils in the relief depressions on the Aral terraces (54–56 m asl). The plant species are mainly shrubs, semishrubs, perennials and annuals from the Chenopodiaceae (*Halostachys*, *Halocnemum*, *Salicornia*, *Suaeda*), some Tamaricaceae, Limoniaceae and Zygophyllaceae. The coverage

Fig. 9.1 *Populus ariana* (syn: *Populus euphratica* s.l.) remnant trees in a short side valley cut in the chinks of the northeastern part of the North Aral Sea (photo: Breckle 2004)

can be rather high, 10–100%. The great variability of this vegetation is a matter of the very varying salinity and water availability. The typical soils are typical solonchaks, as well as takyr-like solonchaks.

The typical tugai biomes are represented by the shrubs and small woods of the delta regions o the Amu Darya and Syr Darya and lake bays. The characteristic species of this vegetation type are mainly *Elaeagnus oxycarpa* and shrubs from the Tamaricaceae. Communities of *Populus* species from the subgenus *Turanga* (*Populus pruinosa*, *Populus diversifolia*) have been preserved as several fragments only in parts along the middle and lower Amu Darya and Syr Darya. A small site with several trees is still in rather good condition in a small hidden side valley between the northeastern chinks of the Small Aral Sea (Fig. 9.1). *Populus* trees depend on available groundwater and spring–summer flooding; they are only slightly resistant to salinity.

The salt meadow vegetation is mainly composed of reed communities with many perennial hemicryptophytes (*Puccinellia* and *Limonium* species, *Aeluropus littoralis*, *Karelinia caspia*, etc.), which can withstand soil salinity. It is spreading in the deltas of the Amu Darya and the Syr Darya and often forms vegetation complexes with tugai vegetation.

9.3 Characteristics of the Vegetation Distribution in the Aralkum

The vegetation of the Aralkum is in various stages of development, mainly on sandy and salty substrates, or with groundwater, and thus can be regarded as pedobiomes, differing from the zonal vegetation mosaic. Figure 9.2 indicates the distribution of the transects for studying this dynamics of the vegetation and ecosystems. The transects stretch from the old coastline to the present one. The vegetation

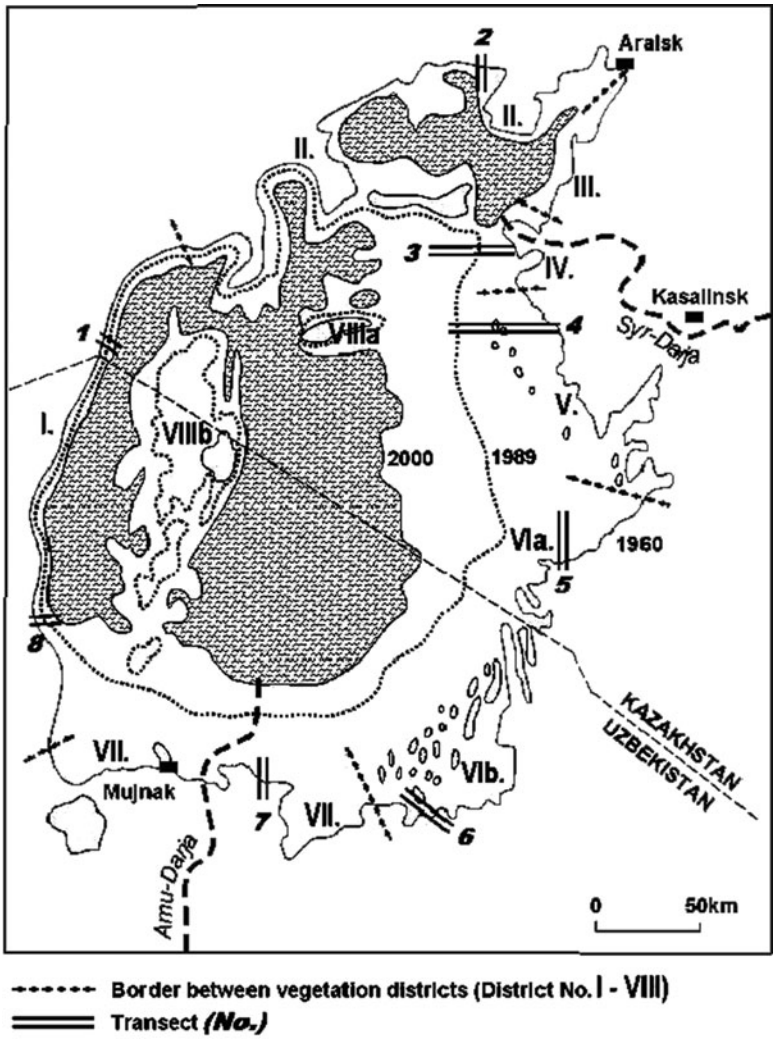

Fig. 9.2 Transects (*1–8*) investigated during recent decades and preliminary definition of vegetation districts (*I–VIII*) of the Aral Sea coastal deserts (according to Kurochkina et al. 1983; Novikova et al. 2001, modified by Wucherer):*I* Usturt district of xerophytic dwarf semishrub vegetation (*Salsola arbusculiformis*, *Artemisia terrae-albae, Anabasis salsa*). *II* Northwestern Priaralye district of haloxerophytic dwarf semishrub and psammophytic grass vegetation (*Anabasis salsa*, *Artemisia pauciflora*, *Artemisia terrae-albae*, *Agropyron fragile*). *III* Northeastern Priaralye district of psammoxerophytic dwarf semishrub and perennial vegetation (*Krascheninnikovia ceratoides, Calligonum aphyllum*, *Agropyron fragile*, *Artemisia terrae-albae*, *Artemisia arenaria*) and several ephemeral species (*Gagea, Iris*, *Tulipa*, *Allium*, etc.). *IV* Syr Darya district of meadow weed–grass, reed and tugaic vegetation (*Elaeagnus oxycarpa*, *Salix* species) in combination with xerophytic dwarf semishrub, halophytic shrub and psammophytic grasses (*Calamagrostis epigeios, Pseudosophora alopecuroides*, *Phragmites australis*, *Artemisia terrae-albae, Halostachys belangeriana*, *Tamarix* spp., *Agropyron fragile*). *V* Eastern district of saxaul

distribution on the transects is very different and depends on the sedimentological patterns of the dry seafloor and the geomorphological and landscape patterns of the former coast. The following three transects are typical examples of the vegetation distribution at the different coasts of the Aral Sea.

The Karabulak transect lies at the northern coast of the Aral Sea (Fig. 9.2, transect 2). The length of this transect is 6 km. The ecological conditions are very hard on the dry seafloor of the 1980 and are more favourable on the dry seafloor of the 1970 (Table 9.1). The plant coverage ranges from 20% to 90% and is especially high in the perennial plant communities with *Phragmites* and *Puccinellia* species (Fig. 9.3, numbers 1–2) and in the therophytic communities with *Salicornia* and *Suaeda* species (Fig. 9.3, numbers 18–21). The perennial plant communities occur at the former coastline. The plant communities with *Salicornia* and *Suaeda* species dominate on the marsh and coastal solonchaks close to the present coastline (as of 1994). On the transect, 56.3% of the area is salt deserts without vegetation, 37.4% is therophytic plant communities and only 6.3% is perennial plant communities (Fig. 9.4). There are 33 species on the transect. The species richness within plant communities is low and ranges from one to 14 species (Fig. 9.5). The species richness is higher on the degraded coastal solonchaks with desalinization of the soil profile. The dominant plant families are Chenopodiaceae, Brassicaceae and Asteraceae. The share of the Chenopodiaceae in the flora of the transect is 46%, that of the Brassicaceae is 24% and that of the Asteraceae is 12% (Fig. 9.6).

The Kabanbai transect lies at the southwestern coast of the Aral Sea (Fig. 9.2, transect 8) and shows the characteristics of vegetation distribution at the open chink. The length of the transect is 3.4 km. The plant coverage is high in the perennial psammophytic plant communities with *Astragalus* and *Stipagrostis* species (Fig. 9.7, numbers 1–3) at the former coastline and in the therophytic communities with *Salicornia europaea* (Fig. 9.7, numbers 9–10) at the present coastline. About 43.1% of the area of the transect is salt deserts without vegetation and 14.8% is salt deserts with a *Salicornia europaea* plant community (Fig. 9.8); 29.8% of the area is barchan deserts without vegetation, and only 12.3% of the area is perennial psammophytic vegetation with *Haloxylon aphyllum*, *Stipagrostis pennata*, and *Astragalus* species. There are 18 species on the transect. The species

Fig. 9.2 (continued) and xerophytic dwarf semishrub and therophyte vegetation (*Haloxylon aphyllum*, *Kalidium caspicum*, *Anabasis salsa, Artemisia terrae-albae*, *Halimocnemis* species). *VI* Southeastern district of saxaul and ephemeral sedge–saxaul–sagebrush vegetation (*Haloxylon aphyllum*, *Haloxylon persicum*, *Artemisia terrae-albae*, *Calligonum* spp., *Carex physodes*). *VIa* With perennial saltworts (*Salsola orientalis, Salsola arbuscula*). *VIb* With psammophytic shrubs (*Salsola richteri*, *Ammodendron conollyi*). *VII* Amu Darya district of tugaic vegetation (*Elaeagnus turcomanica*, *Populus ariana*), halophytic meadow vegetation (*Aeluropus littoralis*, *Sphaerophysa salsula*), halophytic shrub vegetation (*Halostachys belangeriana, Tamarix* spp., *Salsola dendroides*). *VIII* Island district of complex sagebrush–haloxerophytic dwarf semishrub vegetation (*Artemisia terrae-albae–Anabasis salsa*) in combination with saxaul and psammophytic shrub vegetation (*Haloxylon aphyllum*, *Calligonum* spp.). *VIIIa* Barsa-Kelmes. *VIIIb* Vozrozhdeniya. Transects: *1* Beigubek, *2* Karabulak, *3* Bayan, *4* Kaskakulan, *5* Bosai, *6* Akpetki, *7* Muinak, *8* Kabanbai

Table 9.1 Characteristics of the sites along the Karabulak transect (May 1998)

Plant community	Site/soil	Soil horizon (cm)	pH	EC (mS cm)	Dominant plant species
Halocnemum strobilaceum–Ofaiston monandrum community	Crusty solonchak, DSF70	0–0.3	8.49	5.05	*Ofaiston monandrum*, *Halocnemum strobilaceum*
		0.3–7	8.41	6.78	
		7–20	8.38	8.49	
		20–30	8.40	6.13	
		40–50	8.11	11.5	
Halocnemum strobilaceum–Artemisia scopaeformis–Suaeda acuminata community	Degraded coastal solonchak with takyr crust, DSF70	0–3.5	8.54	5.38	*Ofaiston monandrum*, *Climacoptera aralensis*, *Suaeda acuminata*
		3.5–7	8.40	7.00	
		7–19	8.00	2.87	
		19–42	8.27	5.23	
		42–71	8.35	4.45	
		71–100	8.36	5.52	
Suaeda acuminata–ephemeral community	Degraded coastal solonchak (upper soil grained), DSF70	0–2.5	8.53	10.1	*Suaeda acuminata*, *Climacoptera aralensis*, *Strigosella africana*, *Euclidium*
		2.5–10	8.48	1.13	
		10–19	8.05	1.10	
		19–47	8.44	0.48	
		47–80	8.35	29.3	
		80–100	8.26	13.2	
Suaeda acuminata community with *Petrosimonia hirsutissima*	Coastal solonchak (strong loamy), DSF80	0–4.5	8.19	11.3	*Suaeda acuminata*, *Petrosimonia hirsutissima*
		4.5–18	8.48	12.8	
		18–31	8.33	12.1	
		31–50	8.67	31.6	
Climacoptera aralensis (open) community with *Suaeda acuminata*	Coastal solonchak (medium loamy), DSF80	0–6	7.92	3.48	*Climacoptera aralensis*, *Suaeda acuminata*
		6–19	8.29	19.4	
		19–30	8.12	18.6	
		30–50	8.10	6.61	
Suaeda acuminata-Climacoptera aralensis (open) community	Crusty-puffy coastal solonchak (loamy), DSF90	–	–	–	*Climacoptera aralensis*, *Suaeda acuminata*
Suaeda acuminata community	Coastal solonchak (medium loamy), DSF90	0–3.5	8.15	6.82	*Suaeda acuminata*
		3.5–10	8.12	5.58	
		10–20	8.20	7.38	
Suaeda acuminata–Suaeda crassifolia community	Marshy solonchak (medium loamy) groundwater level 16 cm, DSF90	0–5	8.28	3.8	*Suaeda acuminata*, *Suaeda crassifolia*
		5–14	8.36	1.33	

EC electric conductivity of soil suspension, *DSF70* desiccated seafloor from the 1970, *DSF80* desiccated seafloor from the 1980, *DSF90* desiccated seafloor from the 1990

richness within plant communities is low – from one to nine species. The plant diversity decreases from the former to the present coastline (Fig. 9.9). The dominant plant families are Chenopodiaceae, Poaceae and Asteraceae. The share of the Chenopodiaceae in the flora is 42%, that of the Asteraceae is 16% and that of the Poaceae is 11% (Fig. 9.10).

The Kaskakulan transect (Fig. 9.2, transect 4) lies at the eastern coast of the Aral Sea between the former coastline and the former island of Kaskakulan and shows the vegetation distribution at the eastern coast of the Aral Sea on the dry seafloor of the 1960 and the 1970 in the old delta region of the Syr Darya. The length of the

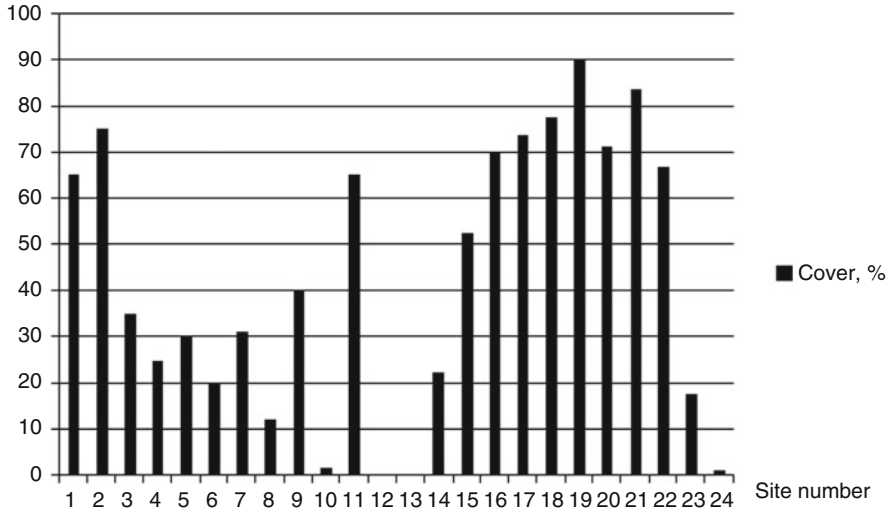

Fig. 9.3 Changes of the cover percentage in the plant communities along the Karabulak transect from the continent (site no. 1), the former coastline from 1960, to the water level of the Aral Sea (site no. *24*) (northern coast of the Aral Sea) (1994)

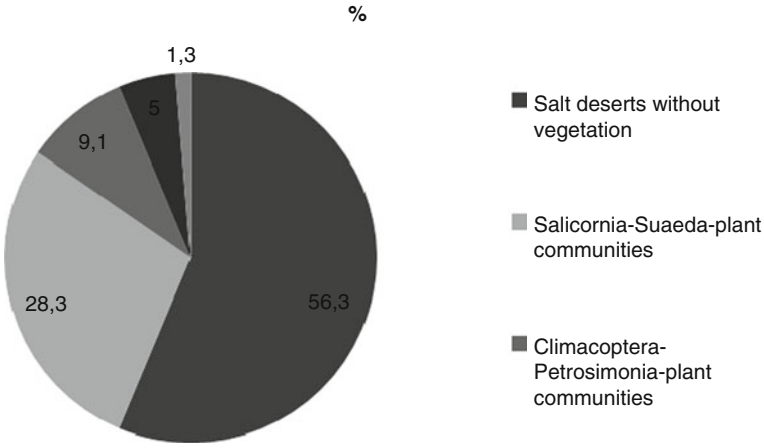

Fig. 9.4 Share of the dominant plant communities and landscapes on the Karabulak transect (northern coast of the Aral Sea) (1994)

transect is 14.9 km. Salt deserts with perennial halophyte vegetation occupy the total area on this transect. The coverage within plant communities is high and ranges from 5% to 80% (Fig. 9.11). The coverage and the species richness are low only for the habitats with high salinity (plant communities 2 and 3). *Haloxylon aphyllum* (48.3%) and *Halocnemum strobilaceum* (34.9%) plant communities dominate (Fig. 9.12). The species richness within plant communities is low and ranges from two to eight species (Fig. 9.13). The species richness is higher on the

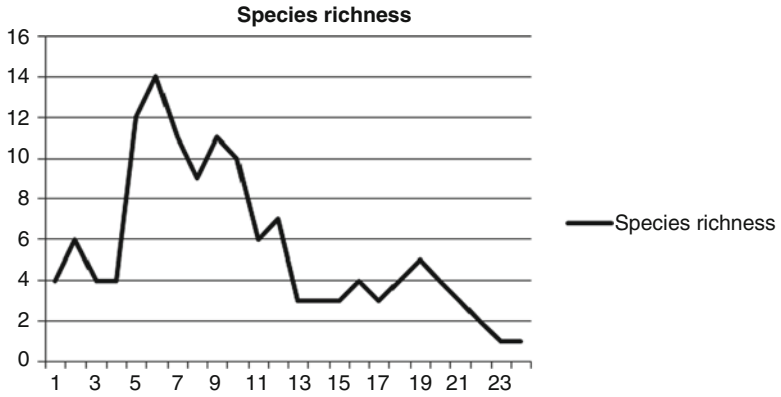

Fig. 9.5 Change of species richness (number of species) in plant communities along the Karabulak transect from the continent (site no. 1), the former coastline from 1960, to the water level of the Aral Sea (site no. 24) (northern coast of the Aral Sea) (1994)

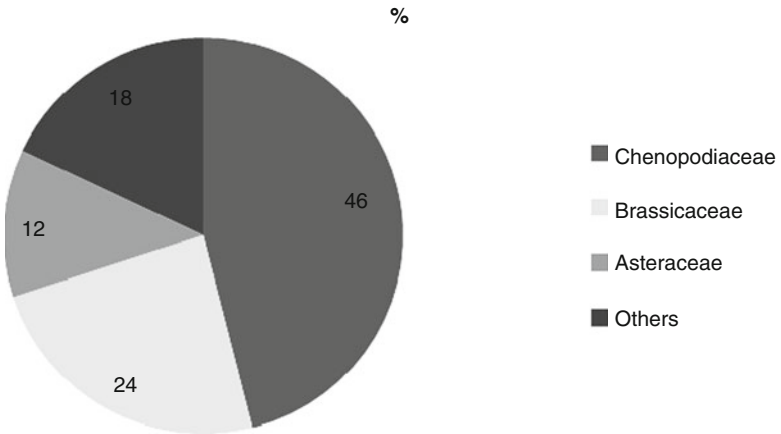

Fig. 9.6 Share of the main plant families on the Karabulak transect (northern coast of the Aral Sea) (1994)

degraded coastal solonchaks in the *Haloxylon* plant communities. The dominant plant families are Chenopodiaceae, Brassicaceae, Asteraceae and Poaceae. The share of the Chenopodiaceae in the flora of the transect is 63%, that of the Brassicaceae is 13% and that of the Poaceae is 13% (Fig. 9.14).

The distribution of the plant communities on the dry seafloor of the 1980 and the 1990 at the eastern coast of the Aral Sea of the Bayan transect is shown on the map in Fig. 9.15. The brown colour depicts the therophytic communities with *Climacoptera* and *Petrosimonia* species (Fig. 9.15). The plant coverage is often rather high, 50–100%. The green colour shows shrub vegetation with *Tamarix* and *Limonium* species and the salt meadows. The salt meadow vegetation mainly

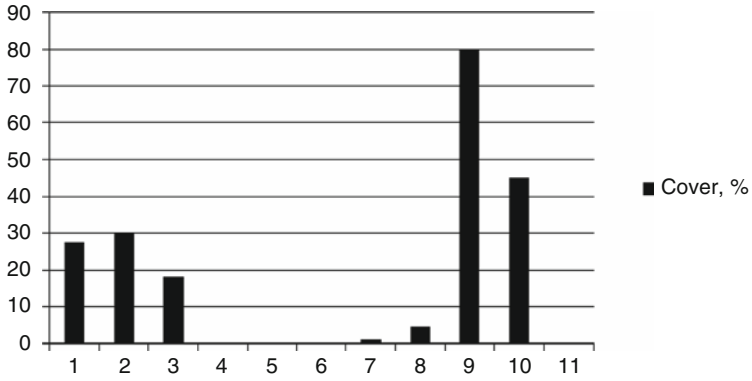

Fig. 9.7 Changes of the cover percentage in the plant communities along the Kabanbai transect from the continent (site no. 1), the former coastline from 1960, to the water level of the Aral Sea (site no. 11) (southwestern coast of the Aral Sea) (1994)

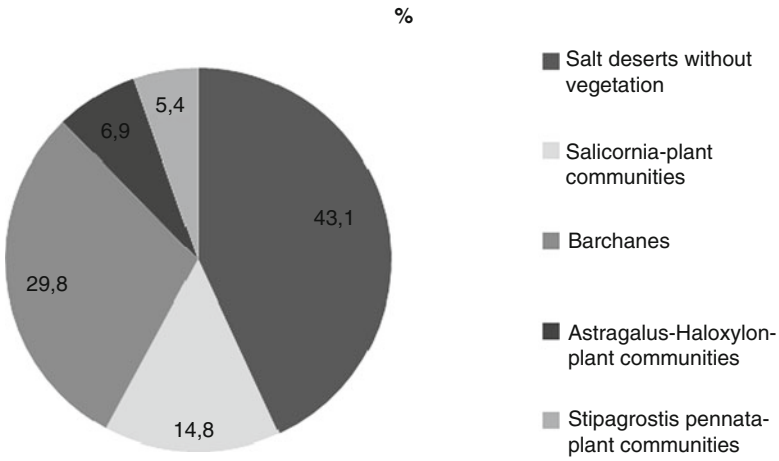

Fig. 9.8 Share of the dominant plant communities and landscapes on the Kabanbai transect (southwestern coast of the Aral Sea) (1994)

comprises reed communities with many perennial hemicryptophytes (*Puccinellia*- and *Limonium*-species, *Aeluropus littoralis*, *Karelinia caspica* etc.). The plant coverage is about 20–60%. The pink and white colours shows the salt deserts without vegetation.

The main vegetation types are as follows: halophytic, psammophytic, tugai and salt meadow communities.

The typical pattern of landscapes, vegetation and soils on the transects is striated. This banded pattern is most characteristically seen along the northern and eastern coasts of the Aral Sea (Ishankulov and Wucherer 1984).

The plant coverage on the transects in the plant communities is very high regarding the prevailing desert conditions, but the species richness is very low.

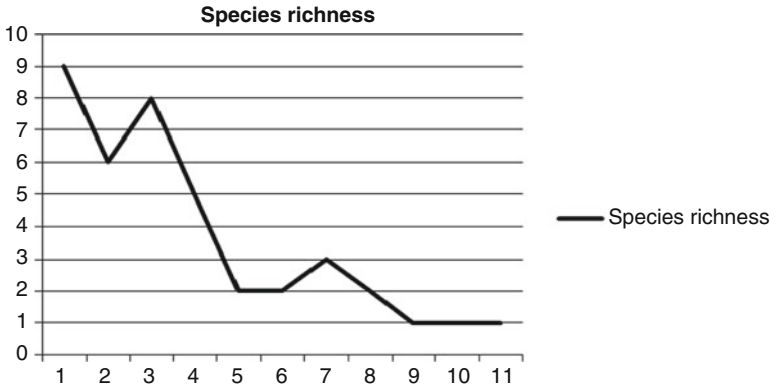

Fig. 9.9 Changes of species richness (number of species) in the plant communities along the Kabanbai transect from the continent (site no. 1), the former coastline from 1960, to the water level of the Aral Sea (site no. 11) (southwestern coast of the Aral Sea) (1994)

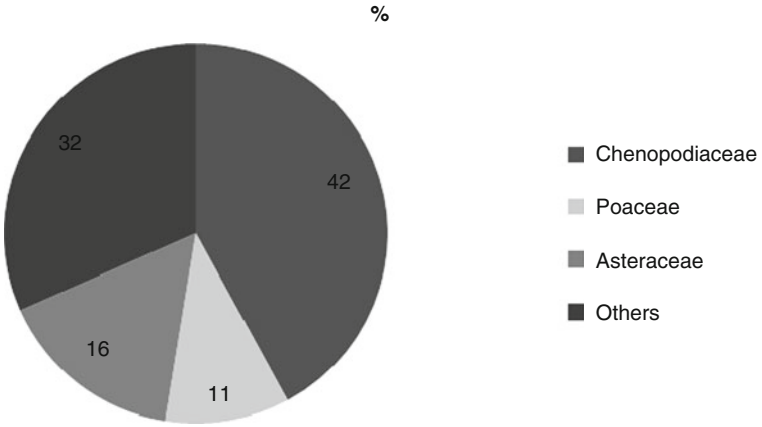

Fig. 9.10 Share of the main plant families on the Kabanbai transect (southwestern coast of the Aral Sea) (1994)

The share of Chenopodiaceae is 40–60% on the transects described. The salt and sand deserts and accordingly the halophytic and psammophytic vegetation types dominate at all types of coast. But the share of the plant communities with perennial vegetation is very low and is only 6–12% on the transects (except for the Kaskakulan transect).

The therophytes and perennials usually form uniform, monotonous stands. Another characteristic is the development of monotonous but very widespread vegetation units on the dry seafloor of the Aral Sea, which is favoured by the fact that there is a huge open flat plain. This is a perfect condition for wide-ranging plant dispersal. The therophytes may cover hundreds of square kilometres within a very short period of less than 2 or 3 years. *Petrosimonia triandra* is a very typical

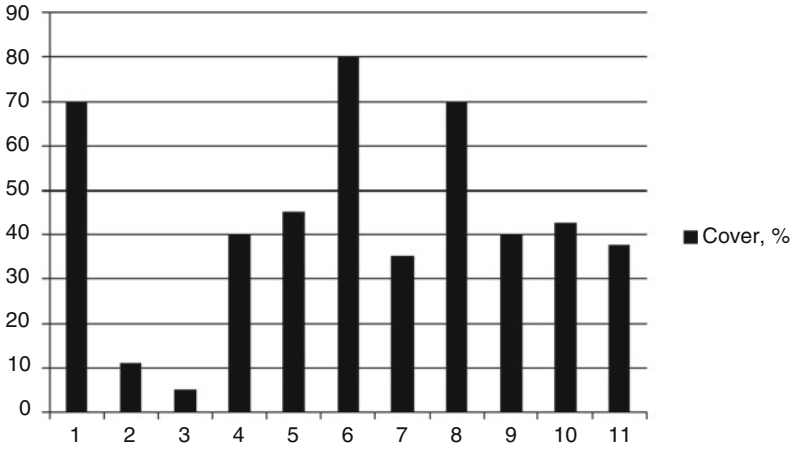

Fig. 9.11 Changes of the cover percentage in the plant communities along the Kaskakulan transect between the continent and the former island of Kaskakulan, from the continent (site no. 1), the former coastline from 1960, to the former island of Kaskakulan (site no. 11) (eastern coast of the Aral Sea) (1994)

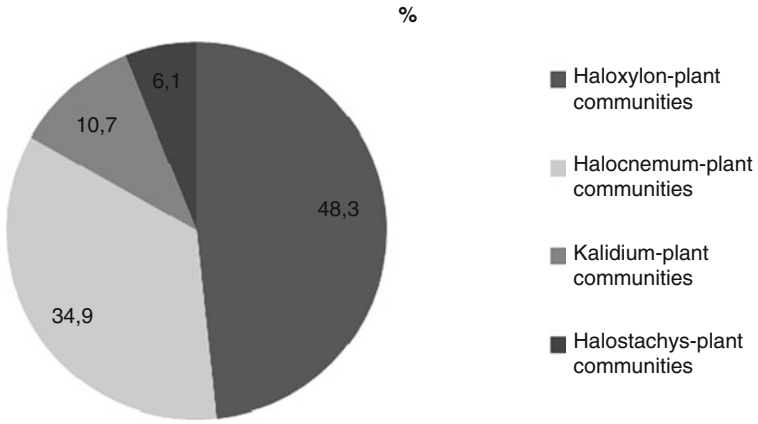

Fig. 9.12 Share of the dominant plant communities and landscapes on the Kaskakulan transect between the continent and the former island of Kaskakulan (eastern coast of the Aral Sea) (1994)

anemochorous plant; it is cut off at the base by wind and then the whole plant is dispersed like the steppe runners by wind over vast distances. Very dense stands were formed by *Petrosimonia triandra* in 1998 on the northwestern coast; *Atriplex pratovii* was extremely dense in 1994 on the southwestern coast. In 2010 *Atriplex pratovii* vegetation occupied a huge area of the dry seabed of the 1990 between the island of Barsa-Kelmes and the original coast. This territory was absolutely bare during the last 20 years. A thin sand layer on the crusty solonchak enables the hemihalophytic *Atriplex* species to overcome the toxic stress. As a rule, those units

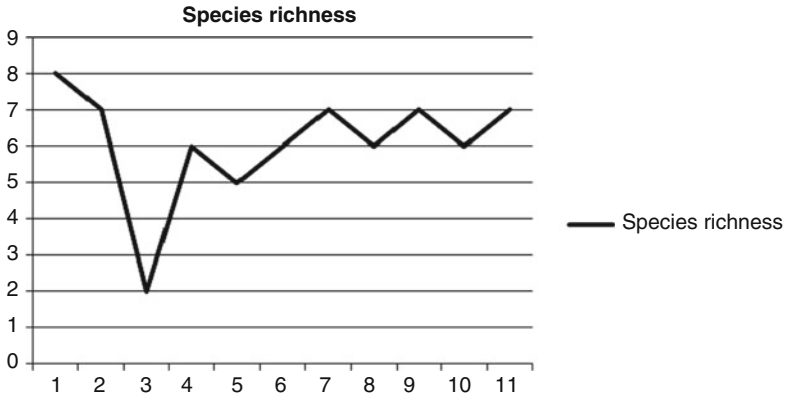

Fig. 9.13 Changes of species richness (number of species) in the plant communities along the Kaskakulan transect between the continent and the former island of Kaskakulan, from the continent (site no. 1), the former coastline from 1960, to the former island of Kaskakulan (site no. 11) (eastern coast of the Aral Sea) (1994)

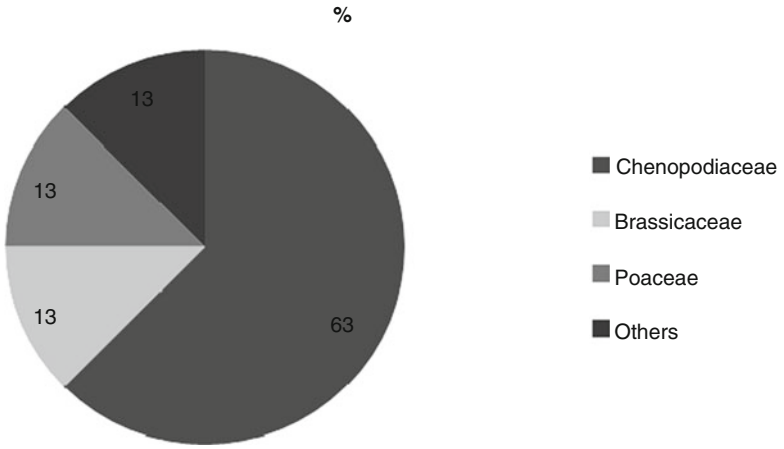

Fig. 9.14 Share of the main plant families on the Kaskakulan transect between the continent and the former island of Kaskakulan (eastern coast of the Aral Sea) (1994)

are often poor in species and over vast distances only three to seven species are found.

Halocnemum strobilaceum, as a succulent chamaephyte, forms extensive stands along the eastern coast of the Aral Sea. Such units are ideal for studies on the genetic and biological variability of these plant populations (Begon et al. 1986). On the other hand, it is almost impossible to define straight plant communities or phytosociological entities with a rather constant species pattern. This is a precondition for naming associations in the sense of phytosociological syntaxonomy. But a description of the common vegetation belts reveals some regularities (Novikova

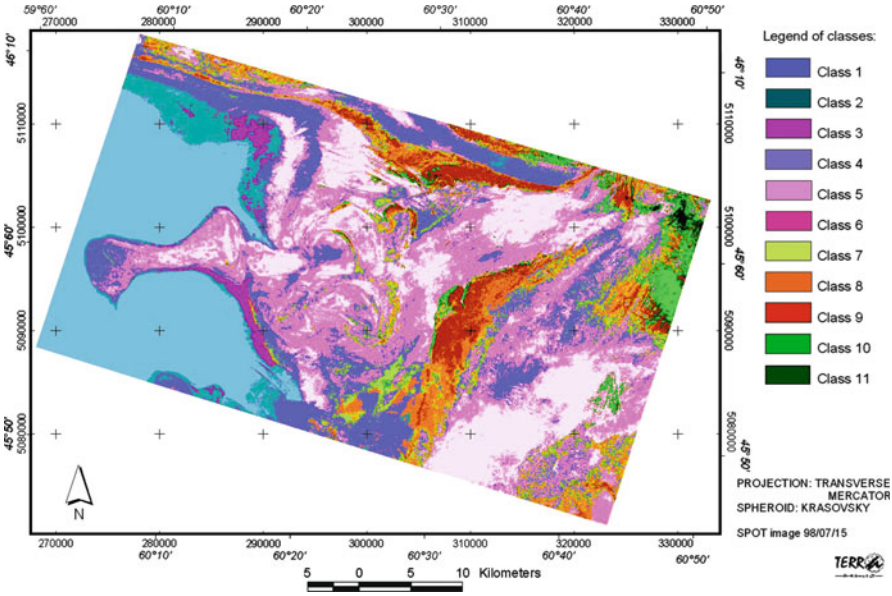

Fig. 9.15 Satellite-derived map. Class 1 sea area, classes 2 and 3 marsh solonchaks partly with *Salicornia europaea* communities, classes 4–6 salt deserts without vegetation, class 7 *Tamarix* plant communities with halophytic therophytes, classes 8 and 9 *Climacoptera aralensis* and *Petrosimonia triandra* plant communities, class 10 *Tamarix* and salt meadow plant communities, class 11 *Phragmites australis* plant community

and Kuzmina 2008), which were given by our intensive investigations (Dimeyeva 1990, Wucherer 1990, Wucherer and Breckle 2001) and are also given in this chapter.

9.4 Main Vegetation Types in the Aralkum

9.4.1 Psammophytic Vegetation

The area of sandy and sandy-loamy sediments is about 12,000 km^2 of the whole Aralkum, mainly in the oldest parts of the desiccated seafloor. This means that sandy deserts with psammophytes are the decisive vegetation around the old coastline, to a great extent at the southeastern and northeasten coasts and around the former islands of Barsa-Kelmes and Vozrozhdeniya. For the whole old coastline, sands with a particle size of about 0.1–0.5 mm are characteristic. Coarser sands are found adjacent to the Syr Darya delta. This sand is predominantly made up of quartz. However, in some parts, limestone particles from sea shells can account for 30–70%. At the eastern coast the limit of sand deposits is at about 43–46 m above

sea level (asl), at the northern coast it is at 48–50 m asl and at the southern coast it goes down to about 33–36 m asl.

The appearance of this sand desert in the Aralkum is dominated by the rather high growing *Haloxylon aphyllum* and *Haloxylon persicum*, *Salsola arbuscula*, *Salsola richteri*, *Salsola paletzkiana* (Chenopodiaceae), *Calligonum* species (Polygonaceae), *Astragalus brachypus*, *Astragalus ammodendron*, *Ammodendron bifolium*, *Ammodendron conollyi*, *Eremosparton aphyllum* (Fabaceae), *Stipagrostis pennata* (Poaceae), *Artemisia arenaria* (Asteraceae) and some species from other families. The main canopy is about 1.0–2.0 m high but can reach 5 m (for *Haloxylon* species). Characteristic therophyte species are *Horaninovia ulicina*, *Agriophyllum squarrosum*, *Salsola paulsenii* and *Corispermum* species from Chenopodiaceae. The canopy is about 20–40 cm high. Typical perennial species are *Allium sabulosum*, *Artemisia santolina*, *Chondrilla brevirostris*, *Heliotropium arguzioides* and *Astragalus lehmannianus*. The plant coverage of the psammophytic plant communities is about 10–40%, rarely up to 80%. The sandy soils exhibit no or only a very slight formation of horizons. Wind erosion causes the development of a complicated relief with all kind of sand dunes. The psammophytic vegetation is most dominant on the dry surface areas from the 1960, is partly dominant on the dry surface areas from the 1970 and is rare on the dry surface areas from the 1980.

At the southeastern coast there are perennial psammophyte communities mainly with grasses such *Stipagrostis pennata* (Fig. 9.16), and also shrubs, e.g. *Eremosparton aphyllum*, *Haloxylon aphyllum*, *Astragalus brachypus* and *Calligonum* species (Wucherer and Breckle 2003).

The sandy deserts of the Aralkum receive approximately 90–120 mm of annual precipitation; the potential evaporation is about 1000 mm per year. Since sandy substrates are the most favourable substrates in arid climates in respect of water budget (Breckle et al. 2008), also these sites in the Aralkum exhibit spontaneous invasion of plants and the formation of an open plant cover. On the desiccated seafloor with sandy substrates, barchans and other sand dune types develop rather quickly by aerodynamic processes. Mainly two types can now be distinguished:

Fig. 9.16 Psammophytic vegetation on the dry sea floor of the 1960 at the southeast coast: *Stipagrostis pennata* plant community with *Haloxylon aphyllum* (photo: Wucherer)

loose open sand dunes with a barchan coverage of 10–50%, and those with a dense barchan coverage of normally over 60%. The most intensive development of dune fields is along the vast stretches of the former eastern coast, where near Kaskakulan it is obvious that they spread to the south and southeast.

9.4.2 Halophytic Vegetation

The halophytic vegetation is present on most of the dry seafloor of the 1970, 1980 and 1990 and especially the more recent desiccated areas. This vegetation is now the most prominent all over the Aralkum. The halobiomes (salt deserts) exhibit typical euhalophytic or hemihalophytic vegetation on more or less saline substrates. A rather considerable portion of the flora (see Chap. 8) is halophytic, mainly from Chenopodiaceae. Their ecological and ecophysiological features are characterized by the fact that they can fulfil their whole life cycle under saline conditions (see Chap. 12). Life forms are shrubs, semishrubs, dwarf shrubs and perennial and annual herbs, mainly from the Chenopodiaceae (*Halostachys*, *Halocnemum*, *Salicornia*, *Suaeda*), but also from Tamaricaceae, Limoniaceae and some other plant families. The canopy height is normally below 1 m, but for adult saxaul shrubs can exceed 3 m. The coverage also varies considerably, ranging between 10 and 100%. A rather high variability in the shape of these forms of halophytic vegetation is correlated with the very variable salinity of the soil and the various soil horizons. Typical soils for halophytic vegetation in the Aralkum are marshy and coastal solonchaks, typical and degraded solonchaks, and takyr-like solonchaks.

9.4.2.1 Annual Vegetation

Close to the retreating water level of the Aral Sea, a rather dense belt of therophytic carpets with *Salicornia europaea*, *Suaeda* species (Fig. 9.17) and *Tripolium vulgare* very often develops. The canopy is about 20–60 cm high, but for *Tripolium* can be up to 120 cm. The coverage of therophytic plant communities ranges between 10 and 100%. *Salicornia* is the main component of the annuals close to the water. But there are also mixtures of some *Suaeda* species (*Suaeda acuminata* and *Suaeda crassifolia*). *Tripolium vulgare* is only present as isolated stands. At the eastern coast near Barsa-Kelmes, aggregations of *Bassia hyssopifolia* are distributed. Adjacent to the delta regions of rivers, mixed stands of *Salicornia europaea* and *Phragmites australis* or *Bassia hyssopifolia* and *Phragmites australis* can be observed. Seeds of *Salicornia* can withstand high salinities, and germination can take place under saline conditions (Willert 1968). Close to the water level the irregular inundations of the marshy solonchaks are favourable for those annuals. The dead remnants from the preceding years can be found everywhere. The development of the therophytic vegetation belt moves according to the retreat of the water level (see Fig. 10.13).

Fig. 9.17 Annual halophytic vegetation on the dry sea floor of the 1990 at the eastern coast (Bayan transect): *Salicornia europaea* plant community with *Suaeda acuminata* (photo: Wucherer)

Fig. 9.18 Annual halophytic vegetation on the dry sea floor of the 1990 at the eastern coast (Bayan transect): *Climacoptera aralensis* plant community with *Petrosimonia triandra* (photo: Wucherer)

On the desiccated seafloor of about 3–10 years after desiccation, we can quite often find a second wave of annuals developing, mainly with *Climacoptera aralensis*, *Petrosimonia triandra*, *Bassia hyssopifolia* and *Atriplex pratovii* on the coastal solonchaks (Fig. 9.18). The canopy is about 20–60 cm high, but for *Atriplex* can be up to 100 cm. But those sites are already under the predominant influence of the zonal climatic conditions which cause rather irregular establishment and growth rates from year to year. The coverage of plant communities ranges between 10 and 100%.

9.4.2.2 Perennial Vegetation

At the eastern coast of the former Aral Sea on the older seafloor from the 1960 and 1970, salinity is moderate or low. Here plant communities with *Haloxylon aphyllum*, *Halocnemum strobilaceum*, *Kalidium caspicum*, *Limonium suffruticosum*,

Fig. 9.19 Perennial halophytic vegetation on the dry sea floor of the 1970 at the eastern coast (Kaskakulan transect): hummock-forming *Halocnemum strobilaceum* plant community (photo: Wucherer)

etc. are found (Fig. 9.19). They form stands with a coverage of 20–40%. On the oversanded coastal solonchaks, rather dense stands with coverage up to 80% can be observed. However, these are small portions in the whole mosaic and are not representative of the whole coast. *Haloxylon* (saxaul) is used by the people for fuel. In 1998 there were massive "deforestations" of saxaul.

On the desiccated seafloor of the 1980 and 1990, there are almost no perennials except for some *Tamarix* or *Halostachys belangeriana* shrubs. Invasion by perennial vegetation is definitely slower than the retreat of the sea level. The conditions for germination and establishment of the perennials is quite favourable on the marshy solonchaks a few years after desiccation, but then in the later phases it becomes much slower and often seems to be hindered.

In 1998 the perennial vegetation on the Karabulak, Bayan and Kaskakulan transects was investigated. Especially the communities with *Tamarix* were checked in the vicinity of the North Aral Sea.

9.4.2.3 Salt Deserts Without Vegetation

The whole seafloor which desiccated from 1980 can be regarded as a huge salt desert flat. It is about 70–80% of the present Aralkum. The therophytic vegetation is spatially and temporally very instable; it affects the soil surface only superficially. In the 1980, when formation of solonchaks had just started, denudation of the desiccated soil surface amounted to about 2 mm year^{-1}; in other words, within 30 years about 6 cm of loose substrate may have been blown away. The present open and often puffy salt crust surface can exhibit windblown losses of 3–7 cm per year.

This makes it important to know which annuals and which perennials are present on those rather open sites of the 1970 and 1980. Those areas are not easy accessible. Within the Bayan transect between the former islands of Barsa-Kelmes and Kokaral

Fig. 9.20 Salt desert on the dry sea floor of the 1990 at the eastern coast (Bayan transect) with crusty solonchak without any vegetation (photo: Wucherer)

it was possible to reach the actual coastline in the 1990. Here, a mosaic of pure open salt desert (Fig. 9.20) and of therophytic stands was present. The more important therophytes were *Suaeda acuminata*, *Petrosimonia triandra* and *Climacoptera aralensis*.

9.4.3 Tugai Vegetation

The tugai biome is characterized by woody vegetation on alluvial soils adjacent to river valleys or delta areas. Along the lower parts of the rivers, mainly *Salix songarica*, *Salix wilhelmsiana*, *Elaeagnus oxycarpa* and shrubs from the Tamaricaceae are dominant. The shallow groundwater and rather often periodic inundations enable good growing conditions for woody plants. Floristically those stands are rather poor. Soils can be somewhat saline, and then halophytes are mixed. The canopy height may reach 8 m, with coverage of 50–100%.

Real *Turanga* forests with adult trees of *Populus* species are rather rare nowadays. The absence of spring–summer flooding and of river-channel straightening are limiting factors for distribution of the floodplain forest on the dry seafloor. Often the original tugai forest is replaced by a dense scrub of *Elaeagnus* and *Tamarix* (*T. laxa*, *T. elongata*, *T. hispida*, *T. ramosissima*) (Fig. 9.21). *Elaeagnus oxycarpa* forms small vegetation fragments and is very local. *Tamarix laxa* and *Tamarix elongata* are more characteristic of the dry seafloor of the 1960 and 1970, *Tamarix hispida* is characteristic of the dry seafloor of the 1980 and 1990 and *Tamarix ramosissima* is characteristic of the dry seafloor of the delta areas. On the dry seafloor of the delta areas, only a *Tamarix* community is present, which also spreads to most of the dunes along the eastern and southern coasts. The canopy height may reach 3 m, with coverage of 30–80%.

Fig. 9.21 Tugai vegetation on the dry sea floor of the 1960 at the eastern coast, in the surroundings of the hot springs (Kaskakulan transect): *Tamarix hispida* plant community with *Tamarix elongata* and *Tamarix laxa* (photo: Wucherer)

9.4.4 Salt Meadows

Some intermediate salt meadows with reed vegetation and perennial hemicryptophytes (*Puccinellia* and *Limonium* species, *Phragmites australis*, *Aeluropus littoralis*, *Karelinia caspica*, etc.) can withstand rather high salinities. *Phragmites australis* forms with *Puccinellia dolicholepis* plant communities at the chink coasts of the former coastline on the dry seafloor of the 1960 with coverage of 60–80%. On the meadow solonchaks at the delta areas a very characteristic *Limonium otolepis–Aeluropus littoralis* plant community with coverage of 40–80% can be found.

9.5 Phytogeographical Zonation

9.5.1 General Remarks

Along the northern and western coasts of the former Aral Sea (Fig. 9.2, regions I and II) the terraces are almost lacking or are relatively small (10–20 m up to a few hundred metres). The main seed source is the intrazonal flora of the terraces and the steep slopes of the chinks. The zonal plant communities of the upper plateaus only marginally influence the flora and vegetation dynamics of the seafloor. In general the Brassicaceae are strongly represented. Species from Fabaceae and Polygonaceae, however, are not so frequent, in contrast to the shallow eastern coastlines (regions III and VI). Here the Aral terraces are rather broad, up to 5 km. The psammophytic vegetation of the adjacent Kyzylkum and the Priaralski Karakum are a main source of diaspores for the seafloor vegetation.

The delta regions (IV, VII) are characterized by irregular flooding from the rivers. Old seed banks are often transported and activated by floods. Tamaricaceae, Cyperaceae and Poaceae are more common, and on some terraces Chenopodiaceae form dominant halophytic associations.

The southern coast (region VII) again has narrow terraces (10–100 m), and these are not important as a seed source. The terraces and the rather low chinks are poor in species. Therophytes prevail and often form strips of vegetation or vegetation belts around lagoons. The former coastline is often a site of a rather dense vegetation belt with a coverage of often more than 20%.

According to the phytogeographical regionalization, the territory of the Aral Sea coast is situated within the Irano-Turanian subregion of the Sahara–Gobi desert region in North Turan province (Lavrenko 1962; Rachkovskaya et al. 2003). The lower units of subdivision – the plant biomes (okrugs and rayons, here called districts) are distinguished according to vegetation features depending on geomorphological features, geological features and soil conditions (Lymarev 1969; Ishankulov 1980; Ishankulov and Wucherer 1984; Kurochkina et al. 1983). The preliminary districts are shown in Fig. 9.2, and a more detailed view of the presently accepted districts is given in Fig. 9.22. A district is represented by regular combinations of vegetation units according to soil, geomorphological features and climate, and is thus somehow similar to a phytosociological unit. The floristic list of one district is typical and there are species missing in adjacent districts. In the limits of a district, all physical-geographical borders are coincident.

The characteristics of the regional subdivisions up to the level of districts were shown by Rachkovskaya and Safronova (1994) The area of the Aral Sea coast belongs to North Aral and East Aral (in the limits of Kazakhstan) and North Ustyurt, Central Ustyurt and Low Amu Darya districts (Uzbekistan). This former regionalization did not take into account the huge territory of the Aralkum. The description of the Aral coast subdivisions up to the level of the lowest units – the rayon – has already been discussed by Dimeyeva (1990) and Dimeyeva and Kurochkina (2005). A change of vegetation cover has to be distinguished especially in the dry seabed. Continued desiccation, increasing mineralization of the seawater, outcrop of marine sediments of heavy texture and salinity have led to a change of direction, speed and the mechanisms of primary successions. On the other hand, there is a process of active colonization of the eastern shore by saxaul vegetation. Future additions and changes to the scheme of zoning will depend on detailed studies especially in the Uzbekistan part of the Aral Sea coast. The shortage of published data on vegetation of the dry seabed there does not allow one to work out the zonation for the whole coastal area. The proposed present scheme of subdivisions therefore covers only the Kazakhstan territory.

The scheme of botanical-geographical zoning is based on the following unpublished maps: map of vegetation of the Aral Sea dry seafloor, scales 1:500,000 and 1:200,000 (Kurochkina et al. 1990); map of vegetation of the Aral region, scale 1:500,000 (Kurochkina et al. 1990); map of ecosystems of the Syr Darya delta (Geldyeva et al. 1998).

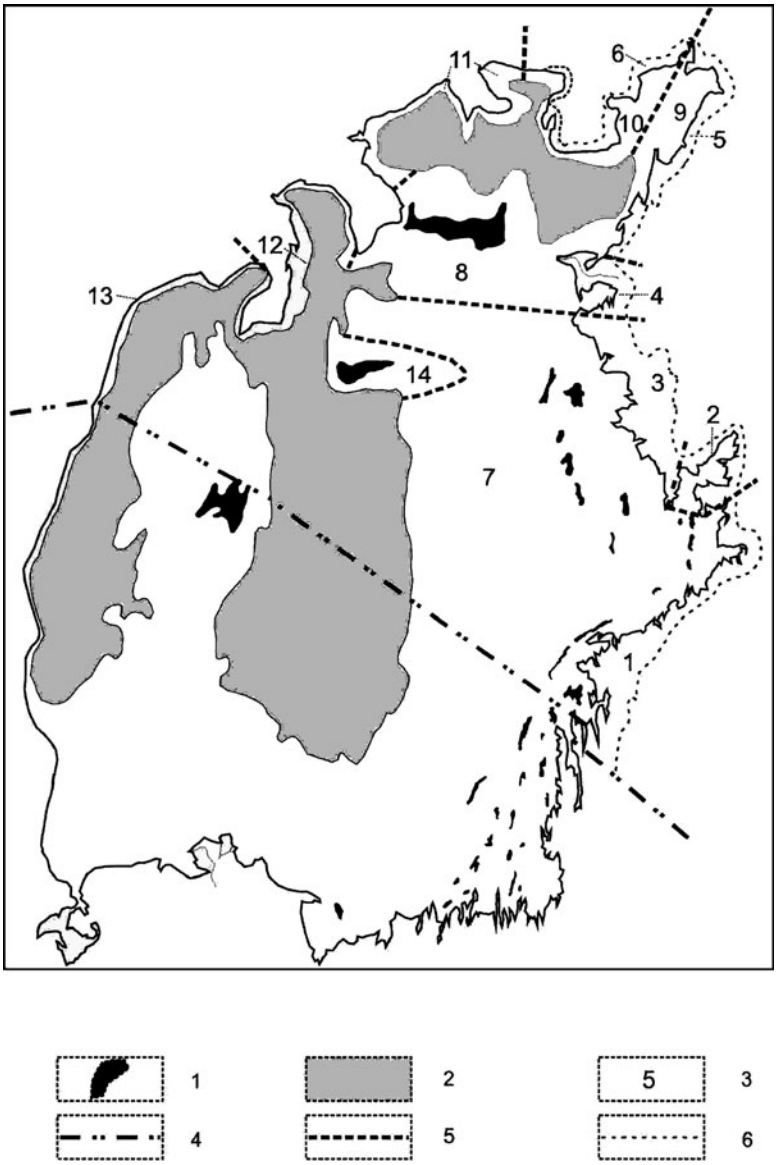

Fig. 9.22 Botanical-geographical zoning of the Aralkum in the limits of Kazakhstan, indicating the present vegetation districts by number (*1–14*). *I* Former islands, *II* the Aral Sea (in 2005), *III* number of botanical-geographical districts (1–14), *IV* boundary of Uzbekistan (Karakalpakstan), *V* boundary of districts, *VI* boundary of old Aral marine terraces

The area of the Aral Sea coast which was subjected to transgressions and regressions during the existence of the Aral Sea since the beginning of the Holocene is called the coastal region. The main features which characterise its vegetation

cover are as follows: uniformity in the origin of the territory which was flooded in ancient and modern times; significant cyclical variations of the sea level; similar trends of successions; incompleteness of successional development and absence of zonal (climax) types of vegetation; depleted floristic composition; the neoendemic species *Atriplex pratovii* is not recorded outside the boundaries of the coastal region. This region is divided into two groups of districts – the ancient terraces of the Aral Sea (Ancient Aral and New Aral marine terraces, Chaps. 2, 3) and the dry seafloor of the Aral Sea (Aralkum). The division into two groups is connected with a different age of the territories and a different degree of successional development. The group of ancient terraces is determined at the eastern and partly at the northern coasts. Ancient terraces are not well defined or occupy a narrow belt on the steep western coast and around the island of Barsa-Kelmes. They were ignored in the general scheme.

Maps of vegetation, native zoning of the Aral coast (Kurochkina et al. 1983; Wucherer and Galieva 1985), floristic characteristics of modern vegetation (Dimeyeva and Kuznetsov 1999; Dimeyeva 2004; Dimeyeva et al. 2008; Wucherer et al. 2001), coastal geomorphology (Lymarev 1969) and sedimentology of marine deposits (Rubanov et al. 1987) were taken into consideration in the division of districts. Fourteen botanical-geographical districts are determined for the Kazakhstan part of the Aral Sea coast (Fig. 9.22). Vegetation characteristics and features of originality of the flora were described for each district. The difficulties accessing the dry seabed of the Kazakhstan part of Vozrozhdeniya did not allow a description of vegetation for this territory to be included. Undoubtedly, it is a separate area with original features of flora and spatial dynamics of vegetation. After investigation of this territory, it may be described as botanical-geographical district number 15.

9.5.2 Botanical-Geographical Status of the Aralkum

The territory of the Aral Sea depression is situated within the Irano-Turanian subregion of the Sahara–Gobi desert region in North Turan province (Rachkovskaya et al. 2003). Only the low Amu Darya district (Uzbekistan) as a fragment of South Turan province borders the southern coast of the Aral Sea. We can distinguish two climatic subdistricts (see Chap. 4, Fig. 4.15) in the Aralkum area – the Aralsk subdistrict in the north (North Turan) and the Muinak subdistrict in the south (South Turan). The climatic border between these two subdistricts runs from west to east through the Aralkum. From a phytogeographical viewpoint, this border is also recognisable, as already mentioned. The following species and their plant communities are the typical indicators of South Turan province:

- *Suaeda arcuata*
- *Suaeda microsperma*
- *Climacoptera turcomanica*

- *Salsola richteri*
- *Salsola paletzkiana*
- *Ephedra strobilacea*
- *Calligonum eriopodum*
- *Ammodendron conollyi*.

The last five species are psammophytes and were mentioned by Kurochkina (2003) as typical southern Turanian indicators.

Three species of halophytes were added to this list by the authors of this chapters after years of research in Central Asia. Furthermore, Wucherer visited the southern coast of the Aral Sea in 1994 and 2000. On the southwestern coast (Kabanbai) and on the southern coast (Adzhibai and Muinak) transects were defined and studied.

Suaeda arcuata is rather common in the delta area and is often found on secondary solonchaks forming small vegetation units in combination with *Suaeda paradoxa*. *Climacoptera turcomanica*, found between Nukus and Kungrad, seems to be also rather typical for South Turan.

In 1994 Wucherer described large-area plant communities of *Suaeda microsperma* in the former bay of Adzhibai and northwest of Muinak on the dry seafloor of the Aral Sea (unpublished data). As a southern Turanian indicator, this species is especially interesting, as it is closely related to *Suaeda acuminata*, which belongs to the section *Conosperma* and is found in the steppe, as well as in northern Turan. *Suaeda acuminata* exceptionally exists and forms plant communities in the Aralsk subdistrict, and *Suaeda microsperma* exists only in the Muinak subdistrict. We also found *Suaeda microsperma* in the large salt depression of Barsa-Kelmes to the west of the southern coast of the Aral Sea. According to Kabulov (1990), this species was also recorded from the Akpetki Archipelago and the adjacent seafloor (southwestern coast). *Suaeda acuminata* cannot be found there.

Salsola richteri and *Salsola paletzkiana*, which are present in plant communities on the dry seafloor at the southern and southeastern coasts, the delta area northwestern Kyzylkum (adjacent to the Akpetki Archipelago) also confirm a southern Turanian character of the Muinak subdistrict. Both species of *Salsola* are very characteristic of the Karakum and are typical southern Turanian species. They do not exist in the Aralsk subdistrict, nor in the coastal area from the former island of Ujaly to Kashkynsu. *Calligonum eriopodum* and *Ephedra strobilacea* are common in northwestern Kyzylkum. *Ammodendron conollyi* is, as already mentioned, regarded as a purely southern Turanian species, even though it also appears in areas further north. It is characteristic of the southeastern coast of the Aral Sea, namely the Akpetki Archipelago, Ujaly and northwestern Kyzylkum.

The southern and southwestern parts of the Aralkum including the dry seafloor and the former island of Ujaly belong to the southern Turanian area. The coast from the former island of Ujaly to the former Kaschkynsu Bay shows a transitional character. These facts led to the conclusion that the border between the northern and the southern Turanian areas to the east of the southeastern coast of the Aral Sea had to be modified.

9.5.3 Vegetation Districts of Ancient Marine Terraces of the Aral Sea

The southeastern (Biktau-Bozkol) district is situated on the southern coast of the Aral Sea (Fig. 19.22, District 1).

It mainly consists of saxaul vegetation with ephemerals, annual saltworts and ephedra (*Haloxylon aphyllum*, *Haloxylon persicum*, *Eremopyrum orientale*, *Salsola nitraria*, *Ephedra distachya*); sagebrush vegetation with ephemerals, teresken, perennial saltworts and black saxaul (*Artemisia terrae-albae*, *Anisantha tectorum*, *Poa bulbosa*, *Krascheninnikovia ceratoides*, *Salsola arbuscula*, *S.orientalis*, *Haloxylon aphyllum*) dominate most plains and hillocky sands. Hilly-ridge sands are vegetated by psammophytic shrub communities (*Calligonum* spp., *Astragalus brachypus*, *Ammodendron conollyi*). Annual and perennial saltwort and tamarisk (*Halocnemum strobilaceum*, *Tamarix laxa*, *Climacoptera aralensis*, *Suaeda acuminata*) vegetation is distributed in the form of a belt, a mosaic-belt according to the ecological range of communities around solonchaks. *Ephedra strobilacea* and *Ammodendron conollyi* are floristic elements of the southern deserts; the presence of representatives of *Eucalligonum* and *Pterigobasis* sections of the genus *Calligonum* (*Calligonum caput-medusae*, *Calligonum erinaceum*, *Calligonum rubens, Calligonum muravljanskyi*) is characteristic of the flora.

Bozkol district is located at the limits of the Kuan Darya delta of the Syr Darya (Fig. 19.22, District 2). It includes the territory of the former bay of Bozkol with the surrounding mainland. Periodically, the former bay is inundated by the river's water. The following plant communities are usually found there: reed with tamarisk (*Phragmites australis*, *Tamarix ramosissima*, *Tamarix laxa*,); perennial saltwort (*Halostachys belangeriana*, *Halocnemum strobilaceum*, *Kalidium caspicum*); and annual saltwort (*Suaeda acuminata*, *Suaeda altissima*, *Climacoptera aralensis*, *Petrosimonia brachiata*). *Climacoptera brachiata – Anabasis aphylla* and *Artemisia terrae-albae – Salsola orientalis* vegetation occupies the takyr-like soils. A typical ecological-dynamic range of communities in the Kuan Darya low stream is as follows: reed (*Phragmites australis*) → liquorice reed (*Phragmites australis*, *Glycyrrhiza glabra*, *Karelinia caspia*) → *Halimodendron halodendron* → annual saltwort (*Suaeda corniculata*, *Atriplex littoralis*, *Atriplex tatarica*, *Petrosimonia brachiata*, *Zygophyllum oxianum*). Vegetation with bog-meadow species (*Bolboschoenus maritimus*, *Eleocharis argyrolepis*, *Eleocharis acicularis*, *Lythrum salicaria*, *Butomus umbellatus*, *Alisma plantago-aquatica*) frequently occupies wetlands.

Agurme-Akkol district (Fig. 19.22, District 3) is situated on the eastern coast from the former Agurme peninsula to the former bay of Akkol. The vegetation cover is characterized by a complex patchiness. Solonchaks are vegetated by communities of *Halocnemum strobilaceum*, *Kalidium caspicum, Nitraria schoberi*, *Tamarix laxa*, *Suaeda physophora*. Communities of *Anabasis aphylla*, *Anabasis salsa* and *Artemisia terrae-albae* are distributed in undulating plains. Sagebrush communities with ephemerals and perennial saltwort (*Artemisia terrae-albae*,

Salsola orientalis, *Eremopyrum orientale*, *Poa bulbosa*) usually occur in a complex with annual saltworts (*Salsola nitraria*, *Climacoptera brachiata*).

Syr Darya district (Fig. 19.22, District 4) is located at the mouth of the Syr Darya. The vegetation is represented by meadow, tugaic and psammophytic plant communities. The following ecological-dynamic ranges of communities are distributed in the delta: reed (*Phragmites australis*) → rush (*Crypsis schoenoides - Juncus gerardii*) → halophytic grasses (*Aeluropus littoralis*); reed–annual saltwort (*Climacoptera aralensis*, *Suaeda altissima*, *Atriplex littoralis*, *Phragmites australis*) → shrubs (*Elaeagnus oxicarpa*, *Tamarix ramosissima*, *Tamarix laxa*, *Tamarix hispida*, *Halimodendron halodendron*, *Lycium ruthenicum*) → forbs (*Calamagrostis epigeios–Glycyrrhyza glabra; Karelinia caspia–Alhagi pseudalhagi*). In plains with sandy areas, communities of psammophilous shrubs, subshrubs (*Ammodendron bifolium*, *Eremosparton aphyllum*, *Convolvulus subsericeus)* and grasses (*Leymus racemosus*, *Stipagrostis pennata*) are distributed. Hillocky sands are occupied by communities of wheat grass–ephemeroid–sagebrush (*Artemisia terrae-albae*, *Poa bulbosa*, *Agropyron fragile*), sagebrush–teresken (*Artemisia terrae-albae*, *Krascheninnikovia ceratoides*) and psammophytic shrubs (*Calligonum* spp., *Ammodendron bifolium*, *Salsola arbuscula*). Original features of the flora are the local distribution of the rare species *Asparagus brachyphyllus* with endemics of Kazakhstan, bulrush (*Scirpus kasachstanicus*) and species from the *Pterococcus* section of *Calligonum* (*Calligonum crispatum*, *Calligonum pseudohumile*, *Calligonum palibinii*).

The northeastern (Bugun-Aralsk) district is situated at the northeastern coast of the Aral Sea from Bugun village to Aralsk town (Fig. 19.22, District 5). The vegetation cover consists of psammophytic communities with an insignificant portion of halophytes (*Tamarix laxa*, *Tamarix hispida*). The typical vegetation of hilly and hilly-range sands is represented by communities of psammophytic sagebrush (*Artemisia terrae-albae, Krascheninnikovia ceratoides*, *Carex physodes*) and psammophytic shrubs (*Calligonum aphyllum*, *Salsola arbuscula*, *Atraphaxis spinosa*) on slopes and tops and wheat grass–sagebrush (*Artemisia terrae-albae*, *Agropyron fragile*) communities in hollows. Anthropogenic modifications of the natural vegetation with invasions of *Peganum harmala*, *Heliotropium arguzioides* and *Euphorbia seguierana* are widely distributed around villages and barns in eroded sands. The original feature of the flora is the occurrence of species only from the *Pterococcus* section of *Calligonum*.

Koktyrnak district is located at the northen coast of the Aral Sea (Koktyrnak peninsula) from Aralsk town to the eastern border of Butakov Bay (Fig. 19.22, District 6). Complexes of perennial saltwort (*Anabasis salsa*, *Suaeda physophora*) and sagebrush (*Artemisia pauciflora*, *Artemisia scopiformis*, *Artemisia terrae-albae*) locally with *Atriplex cana*, *Anabasis aphylla* and *Salsola orientalis* communities are common here. Gentle slopes of ridges are occupied by ephemeral–sagebrush with *Halocnemum strobilaceum*, *Artemisia scopiformis*, *Eremopyrum orientale*, *Rheum tataricum*, and *Lepidium perfoliatum* and ephemeral–sagebrush (*Artemisia terrae-albae*, *Eremopyrum orientale*, *Lepidium perfoliatum*, *Strigosella africana, Meniocus linifolius*) vegetation. Sagebrush communities with teresken,

wheat grass and ephemerals as subdominants (*Artemisia terrae-albae, Krascheninnikovia ceratoides*, *Agropyron fragile*, *Alyssum turkestanicum*, *Poa bulbosa*) are spread in aeolian-active sandy planes. The original feature of the flora is the local occurrence of the relict species *Calligonum bykovii* in breaks, on slopes of ridges and in stony deserts.

9.5.4 Vegetation Districts of the Former Seafloor (Aralkum)

The eastern (Uyaly-Tokpan) district is situated at the eastern coast of the Aral Sea (Fig. 19.22, District 7) from the frontier of Uzbekistan to former village of Tokpan. Characteristic features are a wide distribution of solonchaks and barchan bare lands without any vegetation through high speed of desiccation of the flat seabed. The irregularity of the coastline and multiple former bays determine the formation of solonchaks with perennial saltwort (*Halocnemum strobilaceum*, *Halostachys belangeriana*) vegetation in combination with psammophytic shrub and black saxaul (*Astragalus brachypus*, *Eremosparton aphyllum*, *Calligonum caput-medusae*, *Calligonum densum*, *Calligonum erinaceum*, *Haloxylon aphyllum*) communities. The prevailing spatial sequence of primary succession is a halosere (halophytic shrub and halophytic dwarf subshrubs in late seral stages): *Salicornia europaea* (*Suaeda acuminata*, *Suaeda crassifolia*) → *Atriplex pratovii* (*Climacoptera aralensis*, *Climacoptera ferganica*) → *Halocnemum strobilaceum* (*Nitraria schoberi*). The psammosere is distributed on sandy sediments of the southeastern coast. The spatial sequence is as follows: *Suaeda acuminata*, *Suaeda crassifolia* (*Salicornia europaea*) → *Atriplex pratovii* → *Halocnemum strobilaceum* → psammophyllous shrubs (*Calligonum* spp., *Eremosparton aphyllum*) → *Haloxylon aphyllum*. The psammophytic vegetation of sandy islands was a source of seeds for spreading of psammophilous species to the dry seabed. Sixteen species of *Calligonum* mostly from *Eucalligonum* and *Pterigobasis* sections grown in coastal areas and former islands now occupy the sandy belt of the Aralkum. The territory between the mainland and the islands does not exhibit wide barren lands. It is overgrown with black saxaul, halophilous shrubs, subshrubs (*Haloxylon aphyllum*, *Halostachys belangeriana*, *Kalidium caspicum*, *Suaeda microphylla*) and annual saltworts (*Climacoptera aralensis*, *Halogeton glomeratus*, *Salsola nitraria*, *Atriplex pratovii*). The areas to the west of the former islands are presently bare of any vegetation.

Akkol–Kokaral district is located below the broad delta of the Syr Darya area and surrounds the Kokaral peninsula (Fig. 19.22, District 8). Reed and tamarisk–reed vegetation is distributed in the former bay of Akkol, where discharge of the river water takes place at times. Dry-off surfaces are occupied by *Halostachys belangeriana*. In the avandelta (the smoothly sloping, subhorizontal former underwater accumulative surface being a continuation of a delta area), the forbs (*Aeluropus littoralis*, *Xanthium strumarium*, *Lactuca tatarica*, *Karelinia caspia*, *Puccinellia distans*) and woodreed–willow (*Salix songarica*, *Salix wilhelmsiana*,

Calamagrostis pseudophragmites, *Calamagrostis epigeios*) communities have been formed. Halophytic meadows with annual saltworts and sea aster (*Phragmites australis*, *Bolboschoenus maritimus*, *Suaeda acuminata*, *Salicornia europaea*, *Tripolium vulgare* = *Aster tripolium*) are distributed nearby the river mouth. A territory to the south of the Berg Strait (now Kokaral Dam) is occupied by tamarisk communities (*Tamarix ramosissima*, *Tamarix elongata*, *Atriplex littoralis*, *Bolboschoenus maritimus, Tripolium vulgare, Crypsis schoenoides*).

At 10 km from the dam, the vegetation is characterized by heterogeneity and diversity of plant communities. Psammophytic shrub and psammophytic grass communities (*Calligonum* spp., *Astragalus brachypus, Eremosparton aphyllum*, *Stipagrostis pennata*) with meadow–tugaic species (*Elaeagnus oxycarpa*, *Lycium ruthenicum*, *Glycyrrhiza glabra*) occupy a sand belt of the coast of the 1960. The spatial distribution of seral plant communities on heavy marine sediments is as follows: *Salicornia europaea* (*Suaeda acuminata*) → *Climacoptera aralensis* (*Petrosimonia triandra*) → *Tamarix laxa* (*Tamarix hispida*) → *Halostachys belangeriana* (*Halocnemum strobilaceum*). The northern coast of the Kokaral peninsula is mainly occupied by tamarisk communities (*Tamarix elongata*, *Tamarix hohenackeri*) in combination with psammophytic shrubs (*Astragalus brachypus*, *Eremosparton aphyllum*); the southen coast is characterized by other tamarisks (*Tamarix laxa*, *Tamarix elongata*), sea lavender (*Limonium suffruticosum*) and reed vegetation with some halophilous herbs (*Frankenia hirsuta*, *Karelinia caspia*, *Alhagi pseudalhagi*). Often the dry seabed joins the steep original coast and has *Stipa sareptana* plant communities and aggregations. Communities of *Halocnemum strobilaceum*, *Tamarix laxa*, *Tamarix elongata* and *Lycium ruthenicum* occupy areas to the southwest of the Karatyup peninsula. After the construction of the new Kokaral Dam and the increasing level of the North Aral Sea up to 42 m asl, the former bays of Akkol and Karashalan were flooded. Reed, bulrush and pondweed vegetation (*Phragmites australis*, *Scirpus littoralis*, *Potamogeton perfoliatus*) has developed in those new lakes.

Bugun-Sarychaganak district (Fig. 19.22, District 9) is located at the dry seafloor of the northeastern coast, to the north of Lake Karashalan including the eastern part of Sarychaganak Bay. The typical spatial distribution of seral plant communities is as follows: *Suaeda acuminata* (*Salicornia europaea*) → *Climacoptera aralensis* (*Petrosimonia triandra*) → *Tamarix* spp. (*Halostachys belangeriana*) → psammophytic shrubs and grasses (*Calligonum aphyllum*, *Astragalus brachypus*, *Eremosparton aphyllum*, *Ammodendron bifolium*, *Atraphaxis spinosa*, *Stipagrostis pennata*). The former bays of Bugun, Karatyup and Sarychaganak are vegetated by sarsazan vegetation (*Halocnemum strobilaceum*) in combination with psammophytic shrubs and *Peganum harmala* in Bugun Bay; and with *Atraphaxis spinosa*, *Calligonum aphyllum*, *Limonium suffruticosum*, and *Haloxylon aphyllum* in Karatyup Bay.

Sarychaganak-Butakov district (Fig. 19.22, District 10) is situated at the dry seafloor of the northern coast (the western part of Sarychaganak Bay, the area around the Koktyrnak peninsula and the eastern part of Butakov Bay). The prevailing spatial row of primary succession is a halosere (halophytic shrub and

halophytic dwarf subshrubs in late seral stages): *Salicornia europaea* (*Suaeda acuminata*) → *Climacoptera aralensis* (*Petrosimonia triandra*) → *Halocnemum strobilaceum* (*Tamarix* spp., *Suaeda physophora*, *Limonium suffruticosum*). The psammophytic shrubs (*Calligonum aphyllum*, *Eremosparton aphyllum*, *Salsola arbuscula*) occur in combination with sarsazan and tamarisk communities. Reed, salt grasses, and sagebrush communities (*Phragmites australis*, *Puccinellia distans*, *Artemisia scopiformis*) are distributed in the dry sea belt of the 1960. Indicator species for disturbances (*Anabasis aphylla*, *Peganum harmala*, *Salsola nitraria*) occupy overgrazed areas. The original feature of local conditions is the existence of the territory named Mynbulak ("thousand springs"), where brackish groundwater is pinching out to the surface. Mynbulak is located in the northeastern part of Butakov Bay and has an area of 0.45 ha. The vegetation cover there is composed of meadow–tugaic and many halophilous species (*Tamarix* spp., *Limonium suffruticosum, Limonium gmelinii, Aeluropus littoralis, Atriplex pungens*, *Atriplex pedunculata*, *Atriplex littoralis*, *Phragmites australis*, *Typha angustifolia*, *Scirpus tabernaemontani, Juncus gerardii*, *Crypsis schoenoides*, etc.).

Akespe-Shevchenko district (Fig. 19.22, District 11) begins to the east of Akespe village at Butakov Bay, surrounds the Shubartarauz peninsula and continues to Shevchenko Bay. The prevailing spatial row of primary succession is a psammosere (with a few psammophytic shrubs): *Suaeda acuminata* (*Salicornia europaea*) → *Climacoptera aralensis* (*Petrosimonia triandra*, *Bassia hyssopifolia*) → *Tamarix* spp. → *Calligonum alatum* (*Artemisia arenaria*). The late seral stage on sandy loam and loam sediments is represented by ephemeral–saltwort (*Suaeda physophora*, *Londesia eriantha*, *Climacoptera aralensis*, *Atriplex aucheri, Lepidium perfoliatum*, *Senecio noeanus*) and forb–sagebrush (*Artemisia scopiformis*, *Salsola nitraria*, *Eremopyrum orientale*, *Amberboa turanica*), sometimes with black saxaul (*Haloxylon aphyllum*) or with *Kochia prostrata* (in Shevchenko Bay) plant communities. Reed vegetation occurs often around the Shubartarauz peninsula. Former small bays are vegetated by *Halocnemum strobilaceum.* Overgrazed areas surrounding all villages exhibit only poisonous weed species (*Peganum harmala*, *Anabasis aphylla*) and annual saltworts. The original feature of the flora is a local domination of some endemic species: *Atriplex pungens*, *Petrosimonia hirsutissima* and *Artemisia aralensis*. The eroded sands are occupied by *Artemisia santolina.*

Tshebas-Kulandy district (Fig. 19.22, District 12) is situated at the dry seafloor of Tshebas Bay and surrounds the Kulandy peninsula. The prevailing spatial row of primary succession is a psammosere (with psammophytic shrubs and dwarf subshrubs): *Salicornia europaea* (*Tripolium vulgare*) → *Tamarix laxa* (*Calligonum aphyllum*) → *Calligonum aphyllum* (*Eremosparton aphyllum*, *Atraphaxis spinosa*), *Artemisia terrae-albae* (*Artemisia arenaria*). The late seral stage on sandy loam sediments and coastal soils with a blown-on sand cover is represented by ephemeral–saltwort (*Suaeda physophora, Climacoptera aralensis*, *Eremopyrum orientale*) and ephemeral–black saxaul and with *Calligonum aphyllum* communities. There is sometimes a reed belt which often reaches the shoreline.

Aggregations and communities of *Halocnemum strobilaceum* and *Peganum harmala* surround Kulandy village.

The western (Chernyshev) district (Fig. 19.22, District 13) begins at Chernyshev Bay and continues up to the frontier of Uzbekistan. The prevailing spatial sequence of the primary succession ends with halophytic shrubs and dwarf subshrubs in late seral stages: *Suaeda acuminata* → *Tamarix elongata* (*Tamarix laxa*) → *Atriplex aucheri* (*Suaeda acuminata*, *Petrosimonia hirsutissima*) → *Tamarix laxa* (*Artemisia scopiformis*, *Limonium otolepis*). The phytocenotic characterstic is the distribution of dense tamarisk thickets alternating with annual saltworts (*Atriplex aucheri, Petrosimonia hirsutissima*) in typical belts. Psammophytic vegetation (*Eremosparton aphyllum*, *Calligonum spp.*, *Stipagrostis pennata*) in combination with tamarisk (*Tamarix laxa*) is distributed close to the frontier. The dry sea belt of the 1960 is often occupied by black saxaul and tamarisk–reed vegetation. The original feature of flora is a local domination of *Mausolea eriocarpa*.

Barsa-Kelmes district (Fig. 19.22, District 14) surrounds the former island of Barsa-Kelmes. The prevailing spatial row of primary succession is again a psammosere (up to psammophytic shrubs): *Salicornia europaea* → *Atriplex pratovii* → *Stipagrostis pennata* → *Calligonum spp.* (*Haloxylon aphyllum*). The black saxaul communities are distributed especially at the eastern coast. The southern coast adjoining the cliffs of the island plateau has reed vegetation. The northern coast is occupied by *Halocnemum strobilaceum* communities, often with black saxaul (Dimeyeva and Alimbetova 2006). The western coast is vegetated by communities of *Stipagrostis pennata* and psammophytic shrubs with black saxaul (*Eremosparton aphyllum*, *Calligonum* spp., *Haloxylon aphyllum*).

9.6 Human Impact on Vegetation

The small village of Tastjubek and the Akkuduk camel farm are located on the northeastern coast of Butakov Bay. The camel flock consists of 50 animals. Along this coastline the inhabitants are using the dry seafloor as grazing area and for hay production. The annual *Atriplex* and *Suaeda* species are ideal, as are monotonous salty meadows. The salinization of the upper soil surface, grazing and mowing are preventing the perennial species from spreading out.

As already mentioned, the overgrazed areas surrounding all villages exhibit only poisonous weed species (*Peganum harmala, Anabasis aphylla*, *Salsola nitraria*) and other annual saltworts. A few places which are less saline have been conquered by *Convolvulus arvensis*, *Glycyrrhiza* and other weeds.

Along the former coastline, the inhabitants of adjacent villages are using the dry seafloor more and more as grazing area and for hay production, but also for collecting fuelwood, especially older saxaul and *Tamarix* stems. This could be managed in a way that growth and biomass use reach a high-level equilibrium: thus,

Fig. 9.23 Saxaul (*Haloxylon aphyllum*) community, indicating distinct generations of plants, according to size (photo: Wucherer)

rehabilitation of the environment would also minimise desertification constraints (Breckle 2003). In all these attempts for restoring parts of the dry seafloor and creating a dense vegetation cover, the processes of natural succession have to be maintained and could even accelerated (Wucherer and Breckle 2001).

The wetlands, mainly the tugai forests along the two main rivers Amu Darya and Syr Darya, were greatly used also in the past, but because of sinking water levels their productivity decreased and during further desiccation most of the tugai forests disappeared (Ogar 2001; Novikova 2001). There are good chances to conserve remnants and to restore new areas within the river deltas (Novikova et al. 2001; Novikova and Kuzmina 2008).

9.7 Conclusions

The vegetation of the Aralkum is very dynamic. Rapid changes in composition within 2 years are common, but also subsequent dry years can cause an almost total dieback of pioneer species and the development of open salt desert flats with puffy salt crusts for several years.

The main vegetation types in the Aralkum are halophytic, psammophytic, tugai and salt meadow communities. In general, the canopy pattern is totally dependent on the prevailing climatic situation and the establishment of perennials during subsequent favourable years. Saxaul (*Haloxylon aphyllum*) and *Halocnemum strobilaceum* play a major role in several plant communities on degraded coastal solonschaks. *Haloxylon aphyllum* on the dry seafloor of the 1970 may exhibit about five or six successful establishment events (Fig. 9.23) under natural conditions. This is about every sixth or seventh year on average. Here germination and establishment and subsequent growth leads to a rather rapid conquering of sites.

The psammophytic vegetation (*Haloxylon*, *Calligonum*, *Astragalus* and *Salsola* species) is most dominant on the dry surface areas from the 1960, partly dominant the dry surface areas from the 1970 and rare the dry surface areas from the 1980. The whole seafloor which desiccated from 1980 can be regarded as a huge salt desert flat. It covers about 80% of the present Aralkum. The typical pattern of landscapes, vegetation and soils is striated. The southern and southeastern coasts of the former Aral Sea including the dry seafloor belong to the southern Turanian phytogeographical area, and the western, northern and northeastern coasts belong to the northern Turanian area.

The various regions around the Aral Sea are considerably different in their vegetation history and dynamics, depending also on the adjacent source of diaspores.

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