Section 2

Water Management Situation in the Aral Sea Basin

2.1. Water Management Situation in the Amu Darya and the Syr Darya basins

Water Resources

In 2019, the total annual flow in the basins of the Amu Darya and the Syr Darya was 109.1 km^3 or 93% of average annual flow.

Amu Darya Basin

The annual flow in the basin, including the Amu Darya and its tributaries, as well as the Zarafshan River, was 74.6 km^3, of which 60.31 km^3 in the Amu Darya (at the nominal Kerki section located upstream of the Garagumdarya River). The water content of the Amu Darya in this monitoring section was: 105.5% of the norm in the first quarter; 101% in the growing season; and, 66.7% in the first half of the non-growing season 2019-2020.

As of the 1st of January 2019, the total water storage in the Nurek and Tuyamuyun reservoirs was 11.988 km^3.

Syr Darya Basin

The annual flow in the basin, including the Naryn, Karadarya, and Chirchik and small rivers, amounted to 34.5 km^3, of which 21.64 km^3 of the inflow to three reservoirs – Toktogul, Andizhan, and Charvak – along the Syr Darya.

As of the 1st of January 2019, the total water storage by reservoirs in the basin was 24.98 km^3, including 18.664 km^3 in the key reservoirs in the flow formation zone.

Operation of Reservoir Hydrosystems

The annual inflow to the Nurek reservoir was 21.64 km^3, including 17.44 km^3 (81%) – over the growing season. Water releases from the reservoir were in the amount of 21.44 km^3/year, of which 13.61 km^3 or 63% of annual flow was discharged during the growing season.

Because of lower flow along the Panj River, the annual inflow to the Tuyamuyun reservoir was 30 km^3. This was 0.79 km^3 lower than the forecast, including by 1.9 km^3 lower for the growing season. Annual water releases from the reservoir were 28.68 km^3 or 96% of the value set in the schedule of the BWO Amu Darya. Water releases amounted to 20.06 km^3 or 70% during the growing season.

The annual inflow to the Toktogul reservoir located on the Naryn River was 11.97 km^3, of which 8.81 km^3 (74%) – during the growing season. Annual water releases from the reservoir amounted to 13.777 km^3 and only 5.14 km^3 (37%) were discharged from the reservoir during the growing season. Such re-distribution of flow allowed filling the Toktogul reservoir from 13.6 to 17.2 km^3 during the growing season.

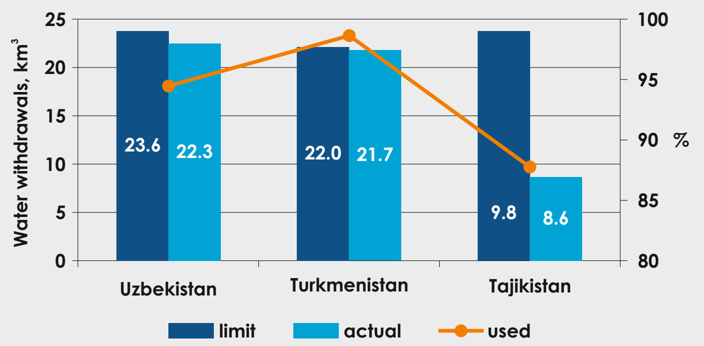
Water Allocation and Shortage

Amu Darya Basin

In 2019, given the established limit of water withdrawal from the Amu Darya at 55.4 km^3, actually 52.6 km^3 were diverted, including 36.12 km^3 during the growing season. 95% of annual water limit was used, of which 91% of the established limit of water withdrawal into canals at 39.67 km^3 – during the growing season. The following situation was observed by countries:

- **Tajikistan** – given the water limit of 9.81 km^3, the actual water withdrawal was 8.61 km^3 or 87.8%;
- **Turkmenistan** – given the water limit of 22.02 km^3, the actual water withdrawal was 21.71 km^3 or 98.6%;
- **Uzbekistan** – given the water limit of 23.59 km^3, the actual water withdrawal was 22.3 km^3 or 94.5%.

Water Limits and Actual Water Withdrawals from Amu Darya in 2019



During the growing season, in the reach from the Nurek HPP to the Tuyamuyun reservoir the water shortage was estimated at 14% in Tajikistan and 5% and 10% in Turkmenistan and Uzbekistan, respectively. In the reach from the Tuyamuyun hydrosystem to the Samanbay post, Turkmenistan and Uzbekistan has received by 4% and 5% less water, respectively, than they required during the growing season.

Syr Darya Basin

The total water withdrawal in the Syr Darya was 12 km^3, including 8.96 km^3 or 76% of the established limit at 11.869 km^3 on water intake to canals during the growing season. 0.548 km^3 of water were discharged from the Syr Darya into Arnasay. The water allocation plan of BWO Syr Darya was on average fulfilled by 79%. In the reach from the Toktogul reservoir to the Chardara reservoir, the water shortage was estimated at 18% in Tajikistan, 33% in Kyrgyzstan, and 34% and 25% in Kazakhstan and Uzbekistan, respectively.

Inflow to the Aral Sea Region

According to the data of the Kazakhstan's Committee for Water Resources, in 2019, inflow into the Northern Aral Sea from the Syr Darya was 3.697 km^3, and 0.83 km^3 were discharged from the Northern Sea into the Large Aral Sea (Eastern part).

Based on SIC's estimates, the South Aral region should receive 8 km^3 of water from the Amu Darya in wet years (in terms of flow) and 3.5 km^3 in dry years. Actually in 2019, 3.21 km^3 or 40% of 8 km^3 was delivered to the South Aral region.

River Channel Water Balance Discrepancies

In 2019, relative lowering of balance discrepancies along the Amu Darya River was observed: 4.45 km^3 during the growing season and 2.1 km^3 during the non-growing season or 6.55 km^3 in total.

Balance discrepancies along the Syr Darya were estimated at 4.59 km^3 (0.87 km^3 during the growing season and 3.72 km^3 during the non-growing season, i.e. decreased by 11% as compared to the previous year (5.17 km^3).

Meeting Demands

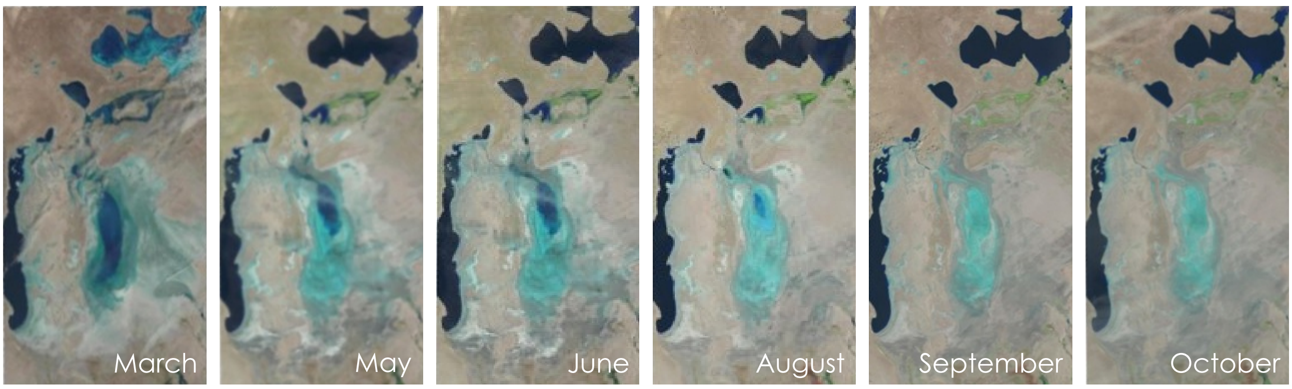
The table below shows how water demands were met among the CA countries.

CA Countries	Meeting water demands in growing season, %	
	Amu Darya	Syr Darya
Kazakhstan	–	66
Kyrgyzstan	–	67
Tajikistan	86	82
Turkmenistan	95	–
Uzbekistan	90	75

2.2. Monitoring of Changes in the Water Surface Area of the Large Aral Sea and the Amu Darya Delta

In 2019, SIC ICWC continued monitoring of changes in the water surface area of the Eastern and Western parts of the Large Aral Sea (LAS) as well as lake systems of the Amu Darya delta through Landsat 8 OLI images (www.cawater-info.net/aral/data/monitoring_amu.htm).

Figure 1. Satellite images of Western and Eastern parts of the Large Aral Sea, *Landsat 8 OLI (2019)*



New methodology. Since 2019, SIC ICWC has been applying a new improved methodology for interpretation of satellite imagery by using the AWEI indexes (Automated Water Extraction Index) for classification of the sea's water surface. Since 2012 to 2019, the satellite data on water surfaces were digitized manually, with the following comparison of NDVI (Normalized Difference Vegetation Index). The new methodology minimizes erroneous interpretation of an area under consideration as the water or land surface (e.g. if plants cover the water's surface). Now, water and non-water sites are classified automatically in "R" and GIS on the basis of spectral water indexes. Accordingly, there could be discrepancies in the data over previous years.

2.2.1. Water Supply to the Aral Sea and the Amu Darya Delta

Water distribution along the Amu Darya

The analysis of water-related situation in the Amu Darya Basin in 2019 (on the data from BWO Amu Darya) shows that, in fact, 4.04 km³ of water (flow from the river and collecting drains) reached the Amu Darya delta (Figures 1 and 2). This is three times more than in 2018.

Additionally, 0.828 km³ of collector-drainage water flowed towards the exposed bed of the Large Aral Sea from the Main South-Karakalpak (Right-bank) collecting drain in 2019 (Table 1).

Figure 2. Dynamics of total water supply to the Amu Darya delta in 2019, *Mm³*

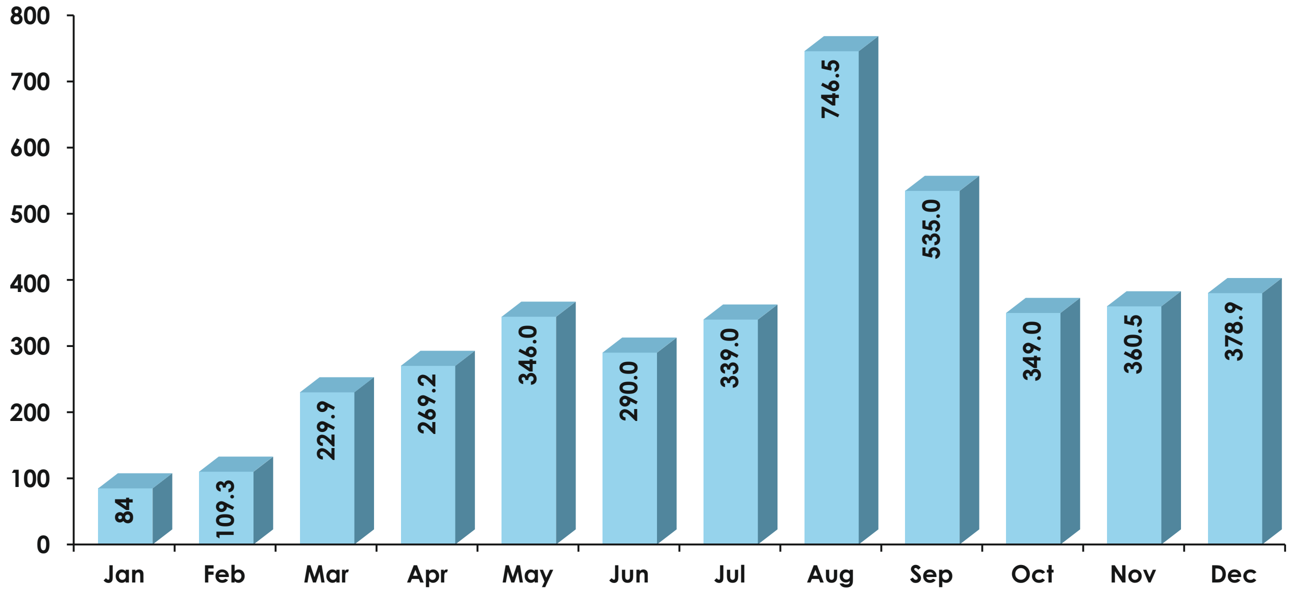


Table 1. Flow of collector-drainage water from the Main South-Karakalpak collecting drain to the exposed bed of the Large Aral Sea in 2019, *Mm³*

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
22.0	27.3	72.9	112.2	108.0	101.0	98.0	79.5	84.0	71.0	44.5	7.9	**828.3**

Total inflow to the Large Aral Sea

As compared to 2018, in 2019, inflow to the Large Aral Sea (1) **increased** from 846 to 1217 km³ from the Amu Darya delta, including collector-drainage water from the Main South Karakalpak collecting drain; (2) **decreased** 4 times from 3.31 to 0.83 km³ from the Northern Aral Sea (NAS) (Table 2). The total amount of water discharge to LAS decreased twofold from 4.156 to 2.047 km³. Water flowing from NAS is partially accumulated in Eastern part, also reaches Western part of LAS, and is partially lost through evaporation and infiltration.

Table 2. Total inflow to LAS, *Mm^3*

Year	Northern Aral Sea		South Aral region		Total discharge into LAS
	Total inflow to NAS from the Syr Darya, Karateren section	Discharge from NAS into LAS	Total inflow to the Amu Darya delta, Samanbay section (incl. collector-drainage water)	Discharge from the Amu Darya delta into LAS	
2018	3,009	3,310	1,715	846	**4,156**
2019	3,697	830	4,037	1,217	**2,047**

2.2.2. Dynamics of Changes in the Open Water Surface and Wetland Area of Eastern and Western Parts of the Large Aral Sea

As monitoring and GIS data shows, from March to September 2019 the water surface area in the Eastern part of LAS shrank from 725,000 to 343,000 ha (Table 3), while the area of the exposed bed **increased** by 382,000 ha (Figure 1). The water surface area in the Western part is also unstable. It **decreased** from 356,000 to 317,000 ha in May-September (Table 3). This is connected with the almost twofold reduced discharge from NAS into LAS.

Table 3. The area of wetlands and open water surfaces in the Eastern and Western parts of the Large Aral Sea, 2019 *(Landsat 8 OLI)*

Month	March	May	June	August	September
Western part of the Large Aral Sea, ha					
Wetland	–	205,045	283,386	292,138	247,019
Water surface	–	356,304	277,964	269,213	317,485
Eastern part of the Large Aral Sea, ha					
Wetland	771,385	921,410	1,053,484	1,166,610	1,153,997
Water surface	725,438	575,413	443,340	330,214	342,826

2.2.3. Lake Systems of the Amu Darya Delta

The lake systems of the Amu Darya delta are represented by small local water bodies of the South Aral region.

Generally, as compared to 2018, the hydrological situation in the South Aral region improved in 2019. The open water surface area of the lake systems increased from 34,200 to 54,500 ha in March-October (Table 4).

An abrupt increase was observed in the second half of the year, when there was inflow of water to the delta (Table 4, Figure 3).

Nevertheless, the actual areas of lake systems account for 10 to 40% of the maximal design area.

Despite the supply of 4.04 km^3 to the Amu Darya delta, stability is not achieved even in those lakes that are used for fishery: Sudoche, Rybache, Muynak and Djiltirbas.

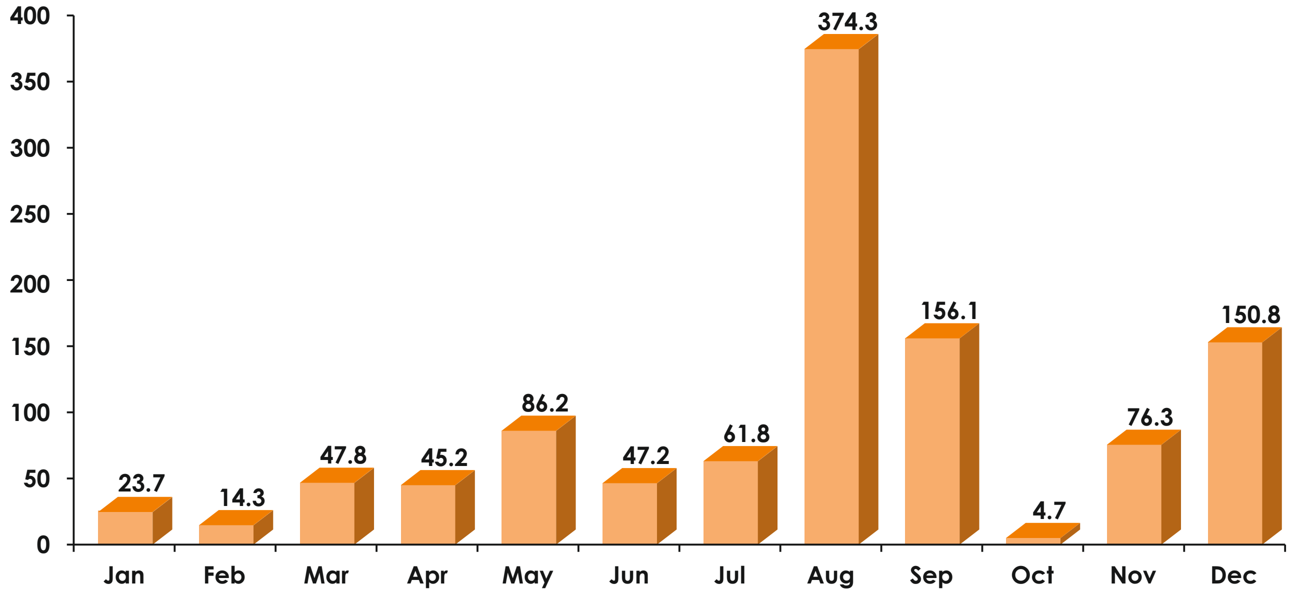
The reason is the lack of a special plan for filling of the lakes with water and the failure to control this process.

Table 4. The area of open water surface of the lake systems in South Aral region in 2019, *ha*

Water body	Design area	Mar 20	May 23	Jun 24	Aug 27	Sep 12	Oct 14
Sudoche	**43,200**	16,940	16,508	14,585	14,173	15,949	18,616
Mejdureche	**32,050**	3,781	5,562	4,922	13,217	11,356	14,471
Rybache	**6,240**	2,641	993	2,383	3,154	2,495	4,234
Maynak	**9,740**	422	361	373	185	253	752
Djiltyrbas dam-terminated	**35,400**	6,001	5,630	5,574	3,620	7,626	7,476
Djiltyrbas (together with former right and left streams)	**62,420**	2,847	2,719	1,171	374	1,905	3,561
Dumalak	**25,630**	3	76	1	651	729	1,109
Makpalkul	**4,750**	863	678	815	1,509	3,109	2,469
Mashan Karadjar	**2,916**	544	727	608	203	824	1,338
Water surface southward of Muynak		60	–	–	–	–	97
Water surface along Kazakhdarya river channel		–	–	–	–	5	3
Zakirkol lake	**2,310**	128	117	96	302	449	396
TOTAL		**34,229**	**33,372**	**30,526**	**37,389**	**44,701**	**54,522**

The increased supply of river water to the delta in the second half of the year (Figure 2) contributes to higher inflow of collector-drainage water to Sudoche lake (Figure 4) from Ustyurt and Kungrad (KKC) collecting drains.

Figure 3. Inflow to Mejdureche reservoir during 2019, *Mm³*



The wetland area of the lake systems in South Aral region decreased slightly – from 305,000 to 285,000 ha – over March-October (Table 5).

Figure 4. Collector-drainage water inflow to Sudoche lake during 2019, *Mm³*

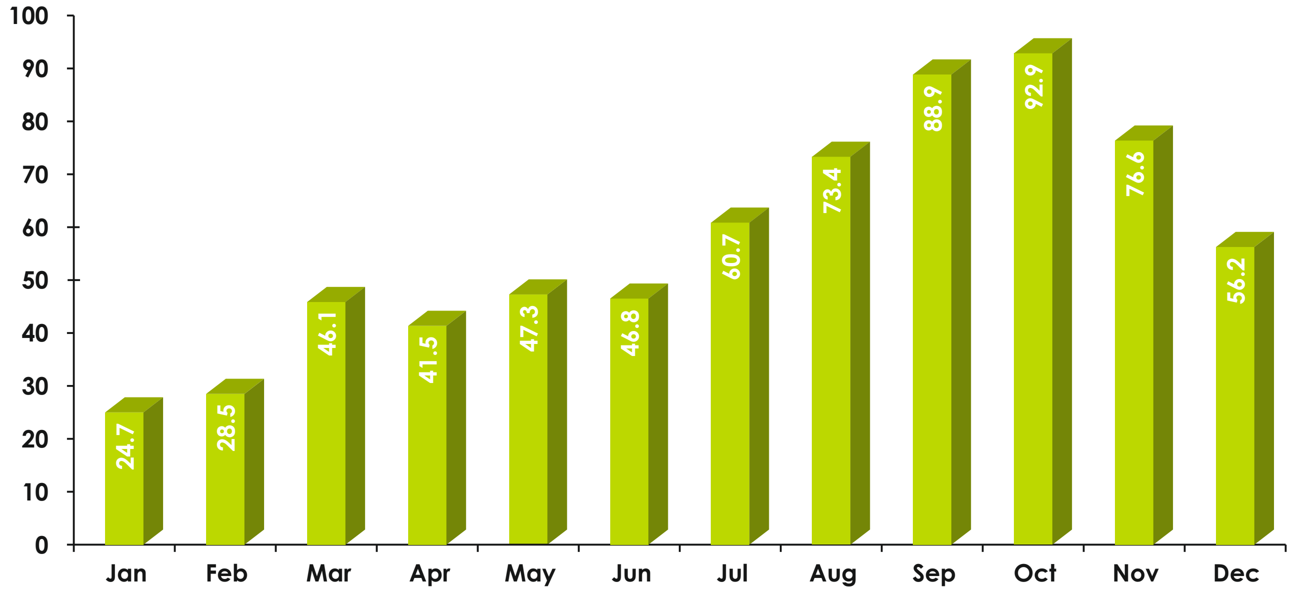


Table 5. Wetland areas of lake systems in the South Aral region in 2019, *ha*

Water body	Mar 20	May 23	Jun 24	Aug 27	Sep 12	Oct 14
Sudoche	41,584	42,016	43,939	44,350	42,574	39,908
Mejdureche	34,003	32,222	32,863	24,567	26,232	23,313
Rybache	8,852	10,500	9,110	8,339	8,881	7,259
Maynak	15,742	15,803	15,791	15,979	15,825	15,412
Djiltyrbas dam-terminated	41,472	41,842	41,899	43,851	38,917	39,997
Djiltyrbas (together with former right and left streams)	96,104	96,232	97,780	98,576	96,565	95,389
Dumalak	16,047	15,974	16,049	15,398	15,281	14,941
Makpalkul	7,821	8,006	7,869	7,174	5,211	6,214
Mashan Karadjar	26,657	26,474	26,594	27,000	26,211	25,863
Water surface southward of Muynak	9,545	9,605	9,605	9,605	9,602	9,508
Water surface along Kazakhdarya river channel	4,752	4,752	4,752	4,752	4,736	4,749
Zakirkol lake	2,664	2,674	2,695	2,488	2,791	2,395
TOTAL	**305,242**	**306,099**	**308,945**	**287,727**	**290,161**	**284,949**

Conclusion

The results of monitoring over changes in the area of water surfaces in Eastern and Western parts of the Large Aral Sea and wetlands of the South Aral region show that in 2019 water inflow was insufficient to ensure environmental stability of local water bodies and maintain water level in the Eastern and Western parts of LAS. The failure to ensure stable water supply hampers efficient implementation of measures for stabilization of ecosystems and socio-economic development in the South Aral region.

Ensuring sustainable water supply for local water bodies in the South Aral region (Table 4) to keep their design areas could yield more than 10,000 tons of fish a year. However, the actual fish catch was 1,800 and 400 tons in 2017 and 2018, respectively. A comparative analysis of the data on the Kazakh part of the Northern Aral Sea shows that the water surface area of the NAS was restored to 330,000 ha. Accordingly, there the fisheries sector yields up to 8,000 tons a year, of which about 2,000 tons of fish are exported to EU.

Source: SIC ICWC research

2.3. Integrated RS-and Ground-Based Studies of the Exposed Bed of the Aral Sea

2.3.1. RS-based Observations over Water Surface and Wetlands of the Large Aral Sea and the Exposed Seabed

SIC ICWC maintains regular monitoring over changes in water surface and wetlands in Eastern and Western parts of LAS based on satellite imagery Landsat 8 OLI (www.cawater-info.net/aral/data/monitoring_amu.htm). The key data of RS-based observations over 2010-2018 is shown below.

Due to unstable inflow, the water surface area in Eastern and Western parts of LAS widely varies and depends on hydrological conditions of a year. In 2018, as compared to the wet year 2010, the water surface area shrank from 380,000 to 275,000 ha in Western part and from 533,000 to 202,000 ha in Eastern part of the sea (Table 6).

As a result of shrinkage of the water surface, the area of wetlands increased by 2018, as compared to 2010, by 107,000 ha in Western part and by 316,000 ha in Eastern part.

The current regime of LAS fully depends on the inflow from the Amu Darya and collecting drains to Eastern and Western bodies and on water discharged from the Northern Aral Sea (Tables 6-7, Figure 5).

The Western and Eastern water bodies remain heavily saline, with salinity ranging from 130 to 350 g/l. In the Western sea, the water level keeps lowering under low water availability, but the depth remains at more than 20 m, while the water salinity is 130 g/l. The shallow Eastern sea depends on discharged water and its volume changes from 1 to 17 km^3, whereas variations of the water level reach almost 3 m.

The ongoing changes in physical and chemical regimes of the Aral Sea affect the current status of the sea's biological systems. Despite huge losses of biodiversity as a result of the environmental disaster, the present biological community of the Aral cannot be referred as dead or dying one. The sea has quite specific but enough active ecosystems consisting of plankton and benthos species that were able to adapt to disastrous salinity. Their total biomass is quite substantial. Attempts are made to catch the dominating zooplankton species in LAS – Artemia shrimp – on a commercial basis. Thus,

Table 6. Comparison of the areas of open water surface and wetlands in LAS (2010-2018), *thousand ha*

Year / Month	2010 March	2011 August	2012 October	2013 August	2014 August	2015 August	2016 August	2017 August	2018 August
Western part of LAS									
Wetland	182.3	165.9	161.3	224.8	186.9	264.6	265.5	283.2	289.4
Water surface	379.6	396.1	369.7	360.7	337.5	315.8	295.8	278.2	275.0
Eastern part of LAS									
Wetland	964.1	1,243.9	1,214.5	1,155.3	1,019.6	1,183.9	1,340.8	1,036.0	1,279.6
Water surface	532.7	252.9	215.9	184.3	103.2	149.2	156.0	460.8	201.7

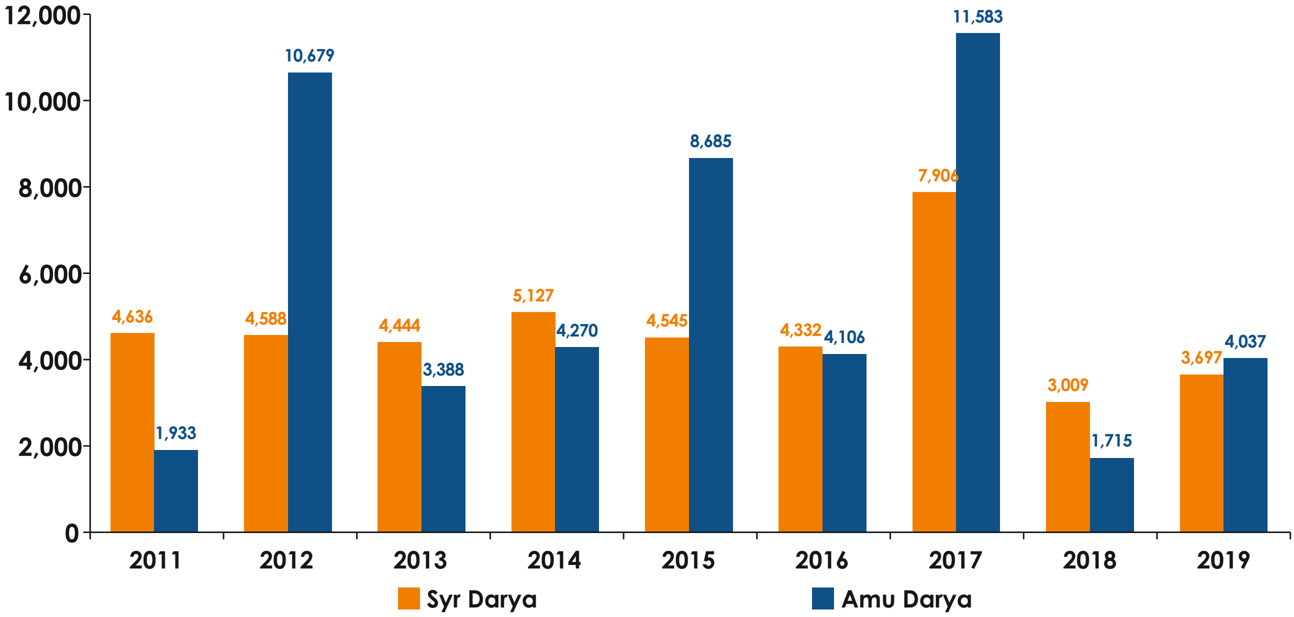
Table 7. Total inflow to LAS, *Mm^3*

Year	Northern Aral Sea		South Aral region		Total discharge into LAS
	Total water supply to NAS from the Syr Darya River, Karateren section	Discharge from NAS into LAS	Total water supply to the Amu Darya delta, Samanbay section (incl. discharge of collector-drainage water)	Discharge from the Amu Darya delta into LAS	
2011	4,636	3,462	1,933	1,041	**4,503**
2012	4,588	2,004	10,679	3,533	**5,537**
2013	4,444	2,424	3,388	2,126	**4,550**
2014	5,127	2,570	4,270	520	**3,090**
2015	4,545	2,440	8,685	4,522	**6,962**
2016	4,332	2,816	4,106	1,874	**4,690**
2017	7,906	6,661	11,583	6,087	**12,748**
2018	3,009	3,310	1,715	846	**4,156**
2019	3,697	830	4,037	1,217	**2,047**

the evolution of biological communities that will be shaped, first of all, by the changes in sea's physical-chemical regime, should be in the focus of future research.

The data on changes in the area of the exposed seabed in the territories of Uzbekistan and Kazakhstan (Figure 6) and water supply (Table 7) indicates to close relationship between these two indicators. This is particularly relevant for the water surface area in ***Eastern water body***, which fully depends on water discharged into the sea. The Eastern body is characterized by an extension of the water surface area if the total inflow to the sea is more than 8 km^3 a year. When the inflow to the sea is less than 6 km^3 a year, the water surface area shrinks (currently, the water level is 26.3 m). For example, when in 2017, the total discharge of water into LAS increased 2.7 times as compared to 2016 and reached

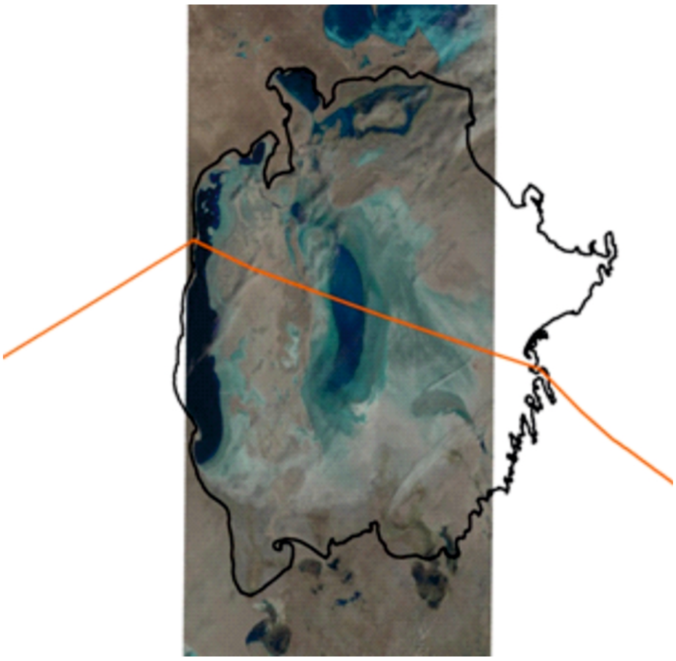
Figure 5. Dynamics of water supply to the deltas of the Syr Darya and the Amu Darya over 2011-2019, *Mm3*



12.7 km^3 (Table 7), the water surface area also increased three times from 156 to 460,810 ha (Table 6). ***The Western body*** is characterized by downward trend of water level (at present, the water level is 24.7 m) and the reduction of the water surface area. The intensity of changes depends on inflow to the sea and water availability in Eastern part (difference in water levels between Eastern and Western parts).

As a result of shrinkage of the Aral Sea, the vast salt desert was formed on an area of more than 5.5 Mha on the exposed bed. Since 2011, the area of the exposed bed of LAS increased from 4.611 to 4.998 Mha, i.e. by 0.386 Mha (Figure 6). Thus, it is important to keep regular monitoring of ongoing processes within the exposed seabed and organize sound management of this complex anthropogenic-natural system.

Figure 6. Dynamics of the area of LAS exposed bed (excluding NAS) over 2005-2019



Year	Total area of LAS exposed bed, km^2
2005	37,661.5
2006	41,028.6
2007	40,562.5
2008	44,666.6
2009	46,232.5
2010	42,955.7
2011	46,112.7
2012	46,971.5
2013	47,349.3
2014	48,950.1
2015	48,063.9
2016	48,645.5
2017	44,747.2
2018	48,018.1
2019	49,981.6

2.3.2. Results of the Expedition to the Exposed Bed of the Aral Sea in September-October 2019

From September 20 to October 20, SIC ICWC together with the International Innovation Center of the Aral Sea Region undertook the first field expedition from two planned ones (for 2019-2020) to the exposed bed of the Aral Sea. The expedition supported as part of a UNDP project through the funds of MPHSTF took place after 10 years since the last expedition to the Aral Sea bed in 2011. Preliminary results of the expedition are described below. The second expedition is planned for May 2020.

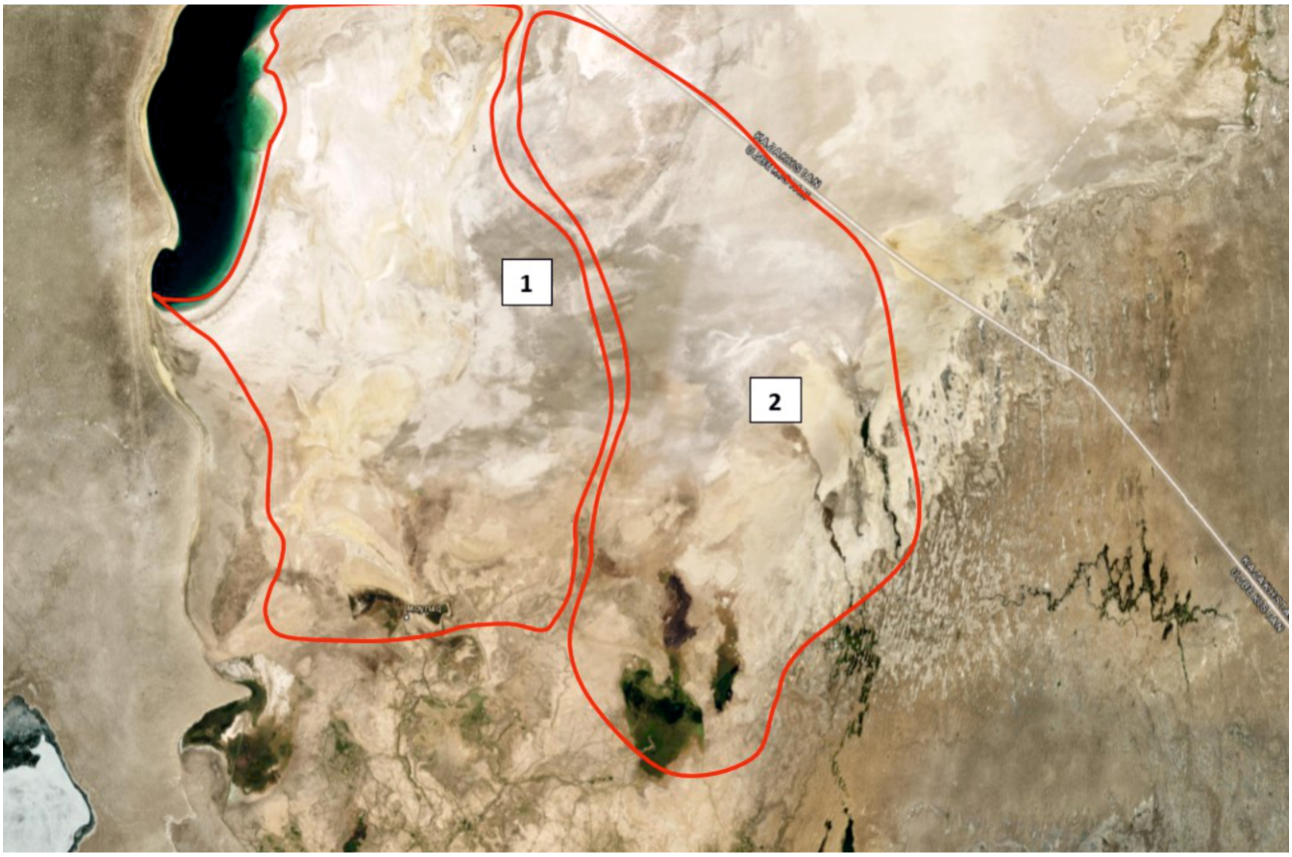
Scope and Methodology

The expedition covered 600,000 ha in Muynak surroundings: from Ustyurt cliff to the former channel of the Amu Darya between the Aral seashore, a watercourse from Rybatskiy bay and the Amu Darya delta (Figure 7).

It was a multi-disciplinary expedition. The following scope of work was completed:

- *Collection of RS-data:* land cover classes from satellite imagery;
- *Hydrogeology:* groundwater table and salinity;
- *Soil:* genetic description, texture, humus, carbonates, gypsum, salinity, salt composition, and soil type;
- *Vegetation:* composition, conditions of natural vegetation and man-made plantations, and assessment of self-organized vegetation;
- *Ecology:* stability of landscapes, risk classes.

Figure 7. The territorial coverage of observations on the exposed seabed by the first and second expeditions



The expedition routes were chosen as close as possible to those previously surveyed by SIC ICWC in 2005-2011. Four camps were set up: in Surgul'; Fitschenko bay; zero end; and, Sarbass. **20 routes** stretched from the camps to survey **1594 GPS points** within 6th to 17th classes.[2] The total route covered **2,500 km**.

The survey results were recorded in an observation log in line with the pre-defined format. All types of vegetation were described in control sites of the exposed seabed, as well as changes in landscapes of the exposed seabed were assessed by comparing the observation data with historical data (including also that of previous ground-based observations) and RS-data. The description of landscape, vegetation and soil cover along each of 20 routes is provided below.

Landscape, Vegetation and Soil Cover in the Surveyed Area

Six routes were taken from the first camp in September 22-26. 249 GPS points were surveyed and described.

Route 1 (44 points). Eastward from the first camp.

The main plant in first points is *Halostachys* with dried-out branches and 20-30% coverage. The land surface has slumps and sinkholes 0.1-0.4 m in diameter. The relief is flat, the surface has crust with shells, and the vegetation cover is 30-40%. Starting from **point 8**, rare vegetation, 0.5 m high, is observed on sandy hills (0.2 m). Plant seeding in

[2] The first 5 classes include the territories with no data (class 1), water surface (classes 2-3), coastal area/inaccessible area (classes 4-5)

spring 2018 has produced nothing. The relief is represented by sand dunes, with sandy hills reaching 10-20 m. The soil is comprised of wet coastal solonchak, semiautomorphic, periodically flushed, with spots of shell, and the vegetation occupies 10%.

Point 15. Rare 5-6-old saxaul, 1.8 m high. There is self-organized vegetation. The soil is under annual grass (dried out after summer). The sowing lines are visible but without vegetation. The relief is flat, with rare dunes. The soil is coastal solonchak, crust, takyr-like, semiautomorphic. Vegetation occupies 10%.

Point 20. There are 4-5-old and plenty of young saxaul plants. As compared to 2007, there is intensive self-organization of vegetation. The vegetation cover is almost 100%, but saxaul is affected by disease. The relief is flat.

Point 22. The territory was flooded before. This resulted in the vegetation cover comprised mainly of tamarisk (60% coverage). The relief is flat.

Point 37. The relief is flat, the soil is compacted due to operation of a drilling aggregate for gas exploration. The vegetation cover is comprised of annual dried-out grass. Furrows are cut in most places along the route to accumulate sand. The furrows, with rarely planted seedlings, virtually have no self-organized vegetation.

Route 2 (51 points). From the camp towards the cliff in southwest and western directions. Plain sloping towards the cliff.

At the start of the route, rare young saxaul plants mixed with dried-out annual grass were observed. The relief is flat, with minor slope and furrows cut for sand accumulation. It is followed by rare dunes with tamarisk and *Halostachys* 0.4-1.0 m high. The relief is flat with very rare bushes on low

dunes. The soil is represented by crust, in placed crust-puffed solonchak, which is wet on the surface and with white spots. There are furrows for sand accumulation. The landscape changes by very rare bushes of tamarisk, *Halostachys*, and *Nitraria schoberi*. The relief is flat, with rare mixed bushes, puffed soil and sand-accumulation furrows. Dried-out seedlings of saxaul were found. Further along the route (**point 92**), mixed vegetation of *Halostachys*, with rare tamarisk is observed. Thanks to an earthen dam, the area before the dam was flooded. There is self-organized vegetation of Halostachys and tamarisk in this area. The fields on the other side of the dam have no vegetation, except for very rare and low dunes with *Nitraria schoberi*. Next (**point 94**), the landscape changes by rare perennial saxaul plants reaching 3.5 m mixed with annual dried-out grass. There are very rare sandy hills with saxaul and *Nitraria schoberi*.

Route 3 (42 points). Northwestward from the first camp

At the beginning of the route, the vegetation is presented by *Halostachys* and tamarisk, with *Climacoptera Botsch* in places. The relief is flat, with sandy loam, light loam from the surface. The territory is divided by earthen dams. Next (**point 96**), tamarisk reaching 2 m in height is observed. *Halostachys* and *Climacoptera Botsch* are also found. The relief is flat, with semi-hydromorphic solonchak periodically flushed. The bare soil is white, with salty spots after drying out. Groundwater is bedded close to the surface.

After flooding in 2017, young plants of tamarisk (0.4-0.7 m in height) grew in place of dried tamarisk bushes. Higher bushes of 1.5-2 m are found along the road, as well as dried-out annual grass and *Climacoptera Botsch*. The relief is flat. Next in **point 103** the landscape changes, rare *Halostachys* and tamarisk associations along the road, as well thick cover of dried-out annual and other grass are observed. The relief is flat, with very rare dried-out grass on hydromorphic solonchak with salt crust. The sand-accumulation furrows are cut.

Next (**point 112**), the vegetation cover is comprised mainly of tamarisk, the density of which is 50% in the area close to the road. Further away from the road, fields with dried-out annual grass and *Climacoptera Botsch* are observed. The relief is flat.

Further on the route (**point 113**) the terrain is flat, the soil is hydromorphic solonchak with salt crust and includes rare annual grasses. The sand-accumulation furrows are cut.

Within **point 118**, the relief is flat. Dried-out annual grasses are observed. Sand-accumulation furrows are cut on both sides of the road. The soil is crust-puffed solonchak.

Route 4 (67 points). Towards Sudoche-Adjibay hydrogeological section, directly north

At the beginning of the route, rare saxaul in association with very rare bushes of tamarisk, *Halostachys* and orach (*Átriplex*) were observed. Flat fields almost have no vegetation cover. The soil has white spots of salt and rare shells on the surface. The sand-accumulation furrows are cut.

Dried-out annual grasses with distant single saxaul and Kandym (*Calligonum sp.*) are observed in **point 182**. The terrain is open and flat. The soil cover is comprised of sand with shells.

Route 5 (48 points). From the first camp to the north, through the Tigrovy Khvost

Rare perennial and young saxaul is observed at the beginning of the route. There is self-organized vegetation, including *Climacoptera Botsch* and *Halostachys* and tamarisk on rare dunes.

Next (**point 209**), the soil is under perennial saxaul (2 m in height) and young saxaul. There is self-organized vegetation. *Climacoptera Botsch*, young drying tamarisk, orach, saltwort (*Sálsola*) and dried-out annual grasses grow there. The terrain is open and flat, and the center of the field is crossed by the asphalt road. The soil is comprised of semiautomorphic, loose crust sand-covered solonchak with shells. The landscape changes by rare perennial saxaul. The terrain is flat. There is a well (Tigrovy Khvost). The well is surrounded by rare perennial saxaul and *Climacoptera Botsch*. More than 3 m high perennial saxaul densely covers the area 60 m far from the well. Since 2006, saxaul plants have grown up to 4 m and expanded (self-organization).

Route 6 (66 points). The road from Muynak to the second camp

At the beginning of the route, there is an open flat terrain under old saxaul on 70-90%. There were a harbor of ships and the Injener-Uzyak channel at **point 289**. The ships were moved to the cemetery of ships in Muynak. Further (**point 312**), rare bushes of perennial saxaul (10-15 years) and single bushes of young self-organized saxaul are observed. *Climacoptera Botsch*, Salsola, and orach are found rarely. The relief is flat, with old cut furrows. Next (**point 313**), rare bushes of perennial saxaul (10-15 years) and Kandym (*Calligonium L.*) grow. *Climacoptera Botsch*, Salsola, orach, and dried-out annual grasses are found. The relief is flat, but hills overgrown with Kandym are found in places.

There are perennial saxaul (up to 3 m in height) and Kandym, annual dried-out grasses, and rare young saxaul plants. Self-organization of plants is observed. The relief is uneven, with blown sand and dunes.

Route 7 (43 points). Road from the second camp northeastward along the Syr Darya River channel

In **points 317-318** saxaul in association with Kandym, as well as orach and *Climacoptera Botsch* are found. The relief is uneven, with sandy hills, 0.5-1.8 m high. Mechanical sand-protection is made of reeds.

In **points 322-326** saxaul in association with Kandym, as well as orach and *Climacoptera Botsch* are found. The relief is flat, but sand dunes 0.5-

0.8 m high are observed in places. The soil is sand-blown, crust solonchak (a salt layer beds at 20-26 cm), semiautomorphic.

Different landscape: very rare tamarisk, single *Halostachys* and also *Climacoptera Botsch*. Furrows are cut for sand accumulation. The soil is crust solonchak.

Point 330. Old perennial saxaul plants, 2-3 m high; 5% vegetation cover; there is self-organization of plants. The terrain is open and flat, with furrows cut for sand accumulation. Further (**point 337**) vegetation changes: *Halostachys* in association

with rare tamarisk are found. The open and flat terrain is subjected to flooding; therefore, it is overgrown with plants. The soil is not salinized and includes shells. At the end of the route (**point 353**), the terrain is open and flat; furrows are cut; the soil is heavily saline, with white spots.

Route 8 (62 points). Eastward from the second camp (Berdybek locality)

Point 357. Rare perennial bushes of saxaul, 1-2.5 m high, Saltwort, *Sálsola*, *Climacoptera Botsch*, and orach are found. The terrain is covered with blown sand, the relief is varied. Perennial saxaul reaches 1.5-3 m; the vegetation cover is 5%. Further, *Sálsola*, orach and dried-out annual grasses are found. The relief is hilly, with sandy hills reaching 3 m.

Point 401. The relief is hilly. Tamarisk up to 2 m high and also shorter tamarisk of 0.4 m in association with rare Halostachys grow on the hills. Saxaul up to 3 m high grows in association with *Sálsola* 0.5-1.2 m high, with 20% coverage. The terrain is hilly at the edge of blown sand. The height of the blown sand reaches 3-4 m.

Route 9 (124 points). First direction – northward from the camp, then, from the second to the third camp

Point 431. Saxaul 1-3 m high in association with *Sálsola*, as well as *Climacoptera Botsch* and dried-out annual grass are found. The terrain is hilly, with 1-1.5 m blown sand. In other points, saxaul 2-3 m high and *Sálsola* are observed. There is self-organized young saxaul. *Climacoptera Botsch* and dried-out annual grass are observed. Rhodiola rosea was found also. Further on the route in **point 452** vegetation changes by tamarisk, 1-2 m. There are also reed, *Climacoptera Botsch*, orach, and very rare saxaul. The relief is flat.

Point 539. The relief is varied. Gasmen built dams and roads. The vegetation cover is comprised of tamarisk and reed, young *Halostachys* and *Climacoptera Botsch*. All plantations of tamarix on newly cut furrows have been dried out.

Route 10 (71 points). From ground zero towards Vozrojdeniye Island

The relief is uneven, with sandy soil and shells. In **point 579**, to the right of the road, saxaul plantations in furrow beds are observed. There is colonization of the plant on 30-40%. Orach, *Climacoptera Botsch* and dried-out annual grasses are observed also. Further on the route in **point 583** and many other points, tamarisk seedlings were planted in furrows. Rare results of such plantations are clearly observed. But most seedlings have dried out. The relief is flat, with furrows. For **points 600-602** the forestry expert M. Ganiev recommended aero-sowing. Next, in **point 606** the relief is hilly, with sandy dunes reaching 1 m and big stones. The vegetation includes Kandym and Selinum.

At the end of the route in **point 615**, furrows are cut on the both sides of the road, and tamarisk seedlings were planted on the left side of the road, but no colonization was observed. Saxaul was sown between furrows. No sprouts are observed. On the right side of the road, tamarisk plantations and saxaul sowing traces are also

observed. However, no positive results are seen. Orach and *Climacoptera Botsch* are found. The relief is flat; the soil is saline, with white spots.

Route 11 (196 points). Continued route 10 from the ground zero towards Vozrojdeniye Island

In **points 625-630** the relief is flat; the soil is heavily saline. Furrows are cut for sand accumulation. Tamarisk seedlings were planted but have not taken root. *Climacoptera Botsch* is rarely found. On the left side of the road the furrows are cut for 100-150 m. Aero-sowing of Kandym was done. Orach, *Climacoptera Botsch* and very rare Kandym are found. The relief is varied, with sandy dunes reaching 1 m; the soil is sandy with shells. Furrows are cut for sand accumulation. Those were also planted with seedlings.

Point 694. The terrain is represented by sandy dunes up to 1 m high. The soil is gypsum-bearing, sandy. There are self-organized Kandym, *Astrāgalus*, saltwort and *Sálsola*.

Point 732. The furrows have fully accumulated sand, and seedlings took roots. The vegetation cover is represented by young saxaul, and *Climacoptera Botsch* and orach are also observed.

Route 12 (91 points). From ground zero towards Muynak

Point 830. Very rare bushes of saxaul, *Climacoptera Botsch*, saltwort and orach. There is self-organized young saxaul.

Point 866. Perennial saxaul plants up to 3 m high are found. Dried-out annual grass is observed in places.

At the end of the route (**point 905**), very rare saxaul, mainly along the road, camel's-thorn (*Alhági*), wormwood (*Artemísia*), *Climacoptera Botsch*, saltwort and dried-out annual grasses are observed. The relief is uneven; there are big dunes 5-20 m high. The soil is sandy.

Point 960. Saxaul, 0.5-2 m, high is mainly found. Rare tamarisk and dried-out annual grass are observed also. The terrain is open and flat. The soil is automorphic crust-puffed solonchak. Saxaul plantation of Temporal afforestation site starts there. Next (**point 1000**), young tamarisk, 0.3-0.4 m high, and rare perennial one reaching 1.7-2 m in height are found together with dense reed and dried-out wormwood. On the one hand, there is self-organized young tamarisk, and, on the other hand, plants dry out.

Point 1006. The terrain is flat. The soil is coastal crust solonchak, wet from the surface, with salt spots and periodically flooded. Rare tamarisk, 1-2 m high, in association with *Halosta-chys* (0.9-1.1 m) is found.

Route 13 (111 points). Along the dam of Muynak bay

Point 928. Mainly reeds, as well as *Climacoptera Botsch* and camel's-thorn are observed at the dam and on escarpment.

Point 948. The open and flat terrain is under tamarisk, 2-4 m high; there is self-organized young tamarisk. Wormwood and saltwort are also found.

Route 14 (93 points). From the cemetery of ships the way towards the former sea coast and downward towards the seabed

Point 1041. On the right side of the road, down the exposed bed the relief is flat. The soil is sandy and crusted. Construction wastes are scattered. Glass and plastic bottles and plastic bags are observed along the route. On the left side of the road, rare bushes of perennial saxaul, tamarisk and *Halostachys* (0.4-1.2 m), as well as rare dried-out annual grasses are observed.

Point 1057. There are saxaul (1-1.5 m), *Astrāgalus*, rare tamarisk, Selinum, and *Aristida L*. Sand dunes reach 1-3 m in height. The soil is comprised of yellow-colored sand.

Further on the route (**points 1057-1062**), there is open hilly terrain. The soil is combined of loose-crust solonchak and sand with shells. The vegetation cover includes saxaul, tamarisk and *Climacoptera Botsch*.

Point 1091. Open flat terrain; desert crust soil, saline, solonchak with white spots; no vegetation.

Point 1107. Landscape changes by sand dunes, 0.5-1 m high. The soil is sanded solonchak, with shells and stone inclusions.

Point 1115. Perennial saxaul (0.5-1.5 m) and young saxaul are observed. There is self-organized vegetation. *Halostachys*, Kandym, Selinum, *Aristida L*, and camel's-thorn are also found.

Route 15 (152 points). From Muynak towards Mejdureche reservoir and then towards the former channel of the Amu Darya via Parlitau

Point 1165 in the direction of Muynak towards Sheghe, head structure of the Muynak canal. At the time of expedition, huge efforts were made at Mejdureche reservoir in order to ensure discharge from the reservoir through the former channel of the Amu Darya to the exposed seabed. The relief is hilly, with elevations ranging from 0.5 to 1 m. The soil is light and covered with grass. Tamarisk, 0.9-1.5 m high, and rarely saxaul, wormwood, and camel's-thorn, *Nitraria schoberi* and *Lýcium* are found.

Further (**point 1184**) the relief is flat, with dry soil and no water. Saxaul, 2-3 m high, camel's-thorn, wormwood, and dried-out annual grasses are found. The relief is flat; it is the coastal strip of the former channel of the Amu Darya. Perennial saxaul, rare tamarisk, and camel's-thorn are found.

Point 1223. Perennial saxaul covering 70%; rare tamarisk. The relief is flat.

Further (**point 1243**), on the left bank of the former channel of the Amu Darya, rare perennial

saxaul and 90% dried-out tamarisk are found. The vegetation cover is about 50%. There is camel's-thorn. The relief is flat.

Route 16. (103 points). From Muynak towards Sudoche lake. The aim of this route – studying the status of the lake and its adjacent area

Point 1272. The relief is flat and open. The soil is crusted solonchak. The vegetation is comprised of saltwort and 0.5 m high *Sálsola*. The vegetation cover is 30%.

Point 1329. Big old saxaul plants (1.5-3 m) and young saxaul are found. There is self-organization of plants. The relief is comprised of sand dunes. Mechanical sand protection of reeds is organized.

Point 1359. The relief is flat. There are old saxaul, 2-3 m high, and dried-out annual grass. Self-organization of saxaul is observed.

Point 1365. Gasmen built dams in some places to protect their structures from flooding. An escape channel was also built. A gas drilling unit is located close. The terrain is open.

Route 17 (31 points). Continued route to Sudoche (route 16), then eastward from the old drill site via dried depression towards Muynak ecosite

Point 1388. The relief is flat at the beginning of the route. The soil is black-colored sandy loam. The area has been flooded, with following overgrowth with tamarisk and, later, *Climacoptera Botsch* started to grow. Tamarisk has dried out on 70-80% of the area, and *Halostachys* (0.5-1 m) is also dried out.

Point 1392-1395. Further elevations of the relief change from 0.5-1 m. There are sandy dunes; the area is open. *Climacoptera Botsch* and rare dried-out grasses are found.

Route 18 (54 points). The road towards "oil drill site" right northward from Muynak

Point 1443. The relief is flat. Furrows are cut for sand accumulation. The area damaged from fire is overgrown with tamarisk. *Halostachys*, dense reed, orach and dried-out annual grasses are rarely found. The soil is crusted solonchak. The furrows were filled with water flowing from Rybache bay.

Route 19 (72 points). From Muynak to Kyzyljar, Tek-Uzek canal. The road crosses the site from Muynak bay to Karadjar settlement, covering the area that was not surveyed before

Point 1460. The relief is flat. Tamarisk and reed, 1-2.5 m high, are found. The vegetation cover is 80%.

Point 1474. The terrain is flat; the soil is dark sandy. Tamarisk, reed, rare *Halostachys*, wormwood, *Climacoptera Botsch* and saltwort are found. Tamarisk reaches 0.5-3 m in height. Saltwort covers 95%. The terrain is open and flat; the soil is crusted solonchak. The channel passes between **points 1518 and 1519**.

Route 20. From Muynak towards south, east and west

Point 1527. The topography is of closed type; the surface is covered with old saxaul. 30 m to the right from the road, the site is dammed.

Point 1555. The relief is flat. There are rare tamarisk and dense reed. The vegetation cover is 100%.

Point 1590. Flat field, with soil subsidence along the road. *Halostachys* is found rarely.

Point 1594. Hilly terrain, with sandy dunes. *Halostachys*, tamarisk, saltwort, *Sálsola* and *Climacoptera Botsch* are found.

Main Findings

The 2019 expedition covered a considerable part of the exposed seabed – 600,000 ha or about 20% of its southwest territory. This territory refers to the earliest dried seabed area, which is characterized by non-uniform processes and sharp differences in landscapes.

The exposed bed of the Aral Sea is a unique laboratory, where a new landscape with gradually forming soil cover evolves under influence of natural processes. At the same time, due to desertification and anthropogenic impact, destructive processes also take place. Formation, development and change of one formation by another one mirror the evolution of landscapes and, first of all, depend on local characteristics of the exposed seabed, the composition of bed sediments, their salinity, groundwater depth and salinity, wind direction and strength and, also, human interventions. Various vegetation covers and landscapes combined with different forms of meso- and micro-relief could be observed along the expedition route.

All those processes are interlinked and impacted by afforestation and, at the same time, have their effect on progress of afforestation. Self-organization of such plants as *Tamarix hispida Willd* (jyngyl) in association with *Halostachys belangeriana Botsch* or *Phragmites australis* (ordinary reed) and dense perennial saxaul bushes was identified.

Water availability, which is sufficiently high in the surveyed area, as compared to the rest of the exposed seabed, **also has its effect on the status of vegetation**. For example, the expedition observed watering of the former Adjibay bay, where water is discharged from the Sudoche Lake system. In the wet year 2017, wet zones were formed around wasteways of Adjibay, where seeds of bushes and other plant types spread and contributed to self-organization of plants on the substantial area.

It is necessary to maintain periodical water spills to save wet zones on the exposed seabed. If re-wetting of the soil on the exposed bed is not maintained for a long period of time, the soil degrades, the water table drops, and soil salinity increases. Biodiversity also deteriorates. The existing vegetation cover starts to dry out.

Operations of gas- and oil facilities on the exposed bed related to construction of roads,

dams, and wasteways with pipes and crosses also hamper self-organization and preservation of plants.

Construction of hydrotechnical structures and utility facilities on the exposed seabed without coordination with local water-management agencies that operate local water bodies in the Aral Sea region also threatens safety of these structures and facilities. The Amu Darya River's flow is very variable, with short-term floods that pose risks to structures.

Structures and roads built by gasmen on the exposed seabed can be utilized for water-management purposes. In particular, from the newly constructed Amu Darya-Sudoche-Adjibay system of watercourses water can be delivered through existing channels and dams to the Western part of LAS.

The negative environmental impact of new infrastructure is also exerted by drilling units that lead to destruction of grass cover and vegetation on the exposed seabed, where ongoing restoration processes are particularly slow. A lot of machines drill wells on the exposed seabed for natural gas production. The vegetation cover has been fully destructed on an area of about 2-3 ha, where drilling units were installed and drilling was completed. Vegetation will not be restored in the drilling sites even after 10 years.

Following decisions of Uzbekistan's leadership, the afforestation process is underway on the exposed seabed. Furrows were cut for accumulation of sand in most places along the expedition's routes. Seedlings were sown in those furrows, but not densely yet, and a minor share of these seedlings took roots.

Self-organization of plants is particularly intensive at the end of plots with man-planted saxaul. This clearly indicates to the positive impact of mitigation measures on environmental situation within the exposed seabed.

Pollution. Trash, including glass and plastic bottle and plastic bags, was found along the expedition's routes. The site with construction wastes occurred close to Muynak. Thus, urgent measures need to be taken by the State Committee for Nature Protection in order to prevent the negative impact on the environment of the exposed bed of the Aral Sea.