Chapter 7

Habitat Analysis of Pelicans as an Indicator of Integrity of the Arid Ecosystems of Central Asia

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INTRODUCTION

Global warming and its consequences need to be considered in the decision-making process on long term land use planning and water resource management. Shrinking glaciers in nearly every mountain range imply that the creeping water crisis is imminent in Central Asia, which had already experienced a crisis in the Aral Sea that is considered by some to be among the most serious water problems of the 20th Century. Moreover, attention should be given to not only the water budget but also the integrity of the water ecosystems that support human life. In March 2007, the environment ministers of the eight leading industrialized countries, the G8, had a two-day meeting focused on ways to preserve biological diversity and combat climate change. The environment ministers of the five major newly industrializing countries – China, India, Brazil, Mexico, and South Africa – also took part for the first time in this annual ministerial meeting. The 13 ministers agreed on a "Potsdam Initiative" on biodiversity that would calculate the economic costs from the extinction of species, said Sigmar Gabriel, the environment minister of Germany (Environment News Service 2007). The meeting participants indicated that the biodiversity crisis has a value equivalent to global warming as a cause of the water crisis.

Arid and semi-arid regions are dominant in Central Asia; however, rivers maintained by glaciers flow down from the mountains and form unique ecosystems with wetlands and riverine forests. It is well known that the large-scale irrigated agriculture, implemented by the former So-

viet Union, altered the wetland ecosystems, and the most sensational result of that activity was the rapid desiccation of the Aral Sea. It appears much more worrisome that such alterations of the basic hydrology in arid regions could degrade the sustainable primary production of the wetland ecosystems, which had been the key resources of human life and wildlife of Central Asia.

The pelican, a large aquatic bird that reaches ten kilos or more, requires large quantities of fish and is considered to be a top predator in the coastal regions. Therefore, sustainable populations of a pelican species could be an indicator of the integrity of the local ecosystems. The pelican species, a victim of the Aral crisis, still has major colonies in the Ili River delta, where large-scale irrigated agriculture, similar to that in the lower Syr Darya River region, had been taking place. The difference between the Ili River delta and the lower Syr Darya River needs to be explored.

In spite of difficult conditions, the Aral Sea dam, which was designed to restore the northern Aral, may hold the solution to the rehabilitation of some of the wetland ecosystems. The recent return of pelicans to the delta supports this supposition. A habitat analysis of the pelicans is provided in the following section to show some of the contributions made to arid and semi-arid regions of Central Asia.

GENERAL CONDITION OF WETLAND ECOSYSTEMS IN ARID CENTRAL ASIA

The Aral Sea Basin is a unique ecosystem in the inland arid region with rivers supported by precipitation in the mountainous regions, including glaciers. Water bodies in the arid areas had been important key resources for living organisms in the region. Caspian or Turanian tigers (*Panthera tigris virgata*), the most westerly ranging tigers, were the top predator of the ecosystem of Central Asia. The Caspian tiger's habitat was the seasonally flooded tugai vegetation growing along the rivers. Tall, dense reed beds grow along the riverside fringed by gallery forests, where *Poplus*, *Salix*, *Eleagnus* species are dominant. Tugai forests are surrounded by tamarisk shrubs, saxaul, and other salt-resistant plants on the desert edge. Tigers and other predators are vulnerable to human

disturbance and habitat destruction resulting from agricultural activities. Along the Syr Darya and Amu Darya Rivers and around Lake Balkhash, the last resident tigers were killed in the 1930s, although there have been several sightings of vagrant tigers in Central Asia.

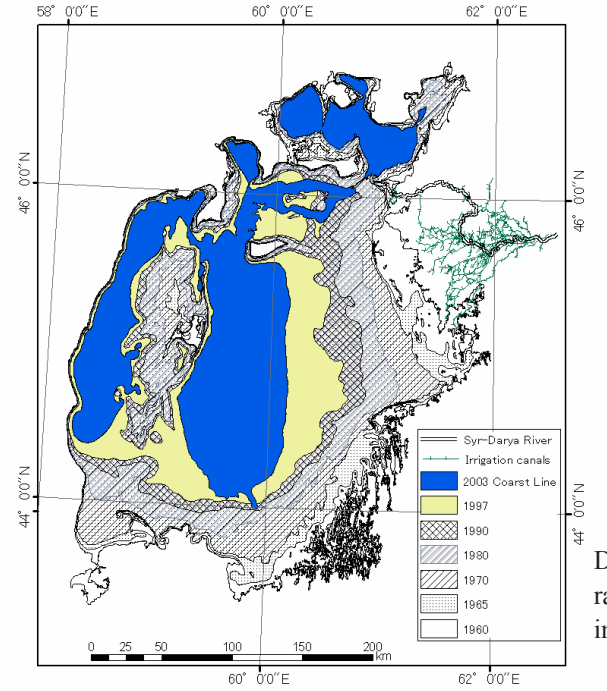
Pelicans, on the other hand, have been the top predator of water body ecosystems. In the Palearctic region, there are two species of pelicans; two thirds of the population of *Pelecanus crispus* and half of that of *P. onocrotalus* inhabit the former Soviet Union. Most of these pelicans were breeding in Kazakhstan in the 1930s when the Aral was the fourth-largest lake in the world. Reed communities, the breeding habitat of pelicans, have disappeared, and fish production has fallen dramatically during the desiccation of the Aral. Therefore, pelicans stopped breeding at the center of the Aral in the 1950s, and the river mouth of the Am Darya and Syr Darya became a limited breeding habitat. Finally, the record of 20 colonies breeding at the mouth of the Syr Darya River was the last one. On the other hand, breeding of both species was recorded at the Am Darya in 1989. Thus, not only to protect the population in the Ili delta, which is the largest colonies, but the restoration of breeding site of pelicans along the Aral could be a very important issue for diversification of extinction risk of pelicans.

STUDY AREAS

The Syr Darya delta and the surrounding regions were selected for detailed ecotope monitoring because of the instability in the Aral catchments caused by humans and the resultant impact on the ecosystems. The Syr Darya deltas, including the desiccated seabed of the Aral Sea around the river mouth, are the most dynamic part of the Aral in terms of ecological disturbance. Since the Aral Sea began shrinking about half a century ago, the bottom of the sea has emerged from the water, and the sea is shrinking at a fast rate even now. Although the Aral Sea has seen repeated reduction and expansion in its long geological history, the speed of change must have been slower than the present reduction; it is clear that unprecedented environmental change is now taking place. In addition, many anthropogenic environmental changes have been occurring in the Syr Darya delta region. Small-scale dams were constructed for ir-

Fig. 1. Aral Sea and Lake Balkhash in Central Asia

Fig. 2. Chronological Shrinkage of the Aral Sea.



Details of the quadrangular area shown in Fig. 4.

rigation at several spots, and a long dam was built between the Northern and the Southern Aral to recover the water level of the Northern (Small) Aral and prevent dam destruction by storm water. On the other hand, desertification processes at the Ili River delta of the Balkhash basin, which is situated in the eastern part of the inland arid area of the Central Asia, is also being monitored as a reference. The situation in the Ili delta is less severe in terms of salinization or desertification and maintains a relatively natural condition in comparison to the Syr Darya delta.

MATERIALS AND METHODS

To investigate the environmental impact and discuss the sustainable land use in this area, it is necessary to evaluate the spatio-temporal event distribution and integrate the data into some models. The various approaches are described below.

Satellite Remote Sensing

Satellite remote sensing is an effective tool for obtaining data sets for a wide area and time series in an area of interest. NOAA/GVI, LAC, and AVHRR 10-day composite data sets were mainly used for the macroscopic observation of the Syr Darya and Ili deltas. To obtain the general status of the desertification of the Aral basin, which is our main objective for monitoring, we used NOAA/AVHRR 10-day composite data sets for analyzing the seasonal changes of this region with a normalized difference vegetation index (NDVI) and compared the Syr Darya delta with the Ili delta as a reference set. Data from Landsat-TM and SPOT HRV/HRVIR were used to evaluate the situation of the deltas in more detail and of the Aral Sea basin in particular; it was also used to evaluate plant succession on the old bottom of the sea. In addition, CORONA Satellite imageries, the spy satellite films, acquired in the 1960s by the USA, were used to elucidate the situation of the Syr Darya delta. Furthermore, Terra/MODIS satellite images were used to analyze the habitat characteristics of pelicans.

Ground Truth Surveys

For the ground-truth field surveys, the land cover, vegetation type, biomass, leaf area index (LAI), soil type, fauna, avifauna, spectral char-

acteristics of ground cover, and ground water level were investigated. For identifying vegetation types, we followed the patch sampling method (Ohsawa 1991). We analyzed the structure and species composition of vegetation and identified each basic unit of vegetation by the physiognomy that forms each ecotope. In addition, line censuses using a helicopter were conducted twice. As reported above, these data were used for supervised classifications, LAI estimations, and other spatial evaluations using satellite images of SPOT/HRVIR and NOAA/AVHRR. The river water flow rate and meteorological data, except online public domain data, were provided by institutes in Kazakhstan.

Habitat Suitability Estimation and Habitat Modeling for Pelicans

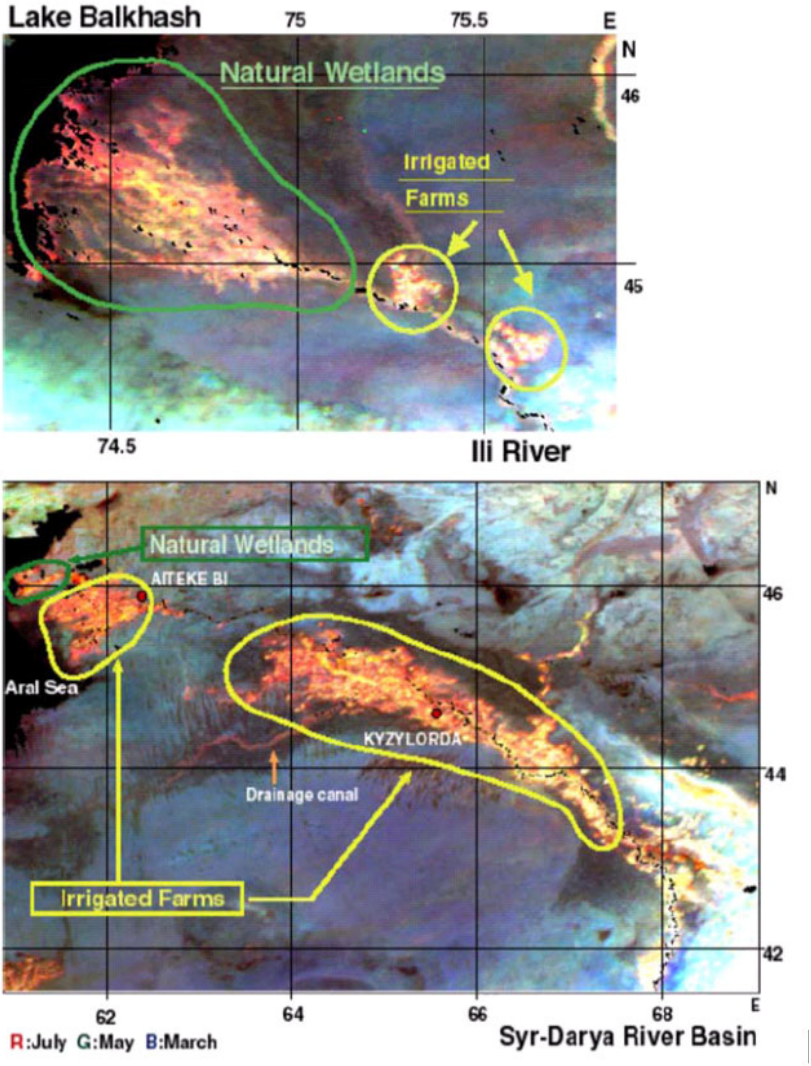
We took bird censuses to identify suitable habitats for pelicans and surveyed all major lakes in the Syr Darya delta in the summer. To identify the wintering sites and the migration route, including stepping sites, we tracked three pelicans. We captured three juveniles at Sorblak Lake (43.68°N, 76.56°E), 40 km north of Almaty, Kazakhstan, on 24 July 2002. The lake is an artificial reservoir of about 60 km^2 with a small island where approximately 200 pairs of *Pelecanus crispus* nested during the year. We attached satellite telemetry transmitters (PTT-95, Microwave Telemetry) on the pelicans. The transmitters were placed on the dorsal surface of the pelicans between the wings using a harness. We tracked their migration route using the ARGOS satellite data collection system developed by NASA and NOAA.

RESULTS AND DISCUSSION

Overview: Using NOAA/AVHRR Data

A general view of land-use and vegetation distribution patterns was obtained by color synthesis of NOAA images as shown in Fig. 1. This image was created using good-quality NOAA/AVHRR 10-day composite data sets to observe the seasonal change of the vegetation index without the noise of clouds on as clear a day as possible using the best scene for each 10-day period. This image was created by three vegetation indices: Red = July, Green = May, and Blue = March, so that we could distinguish the seasonal changes by color.

Fig. 3. Comparison of the Ili Basin with the Syr Darya Basin by the Seasonal Activity of Vegetation



Color synthesis using NDVI for July, May, and March (red, green, and blue, respectively) clearly shows the wetland vegetation.

The difference between the Aral Sea Basin and the Balkhash Basin can be seen at a glance. Spring type vegetation, which is supported by spring rainfall, is distributed widely in the arid and semi-arid Central Asia, and wetland vegetation, which is supported by river water, is distributed along rivers and deltas, showing maximum activity in summer. By correlation analysis, spring vegetation types proved to be significantly correlated with precipitation data. Until now, from a geobotanical viewpoint, the distribution pattern of these types of vegetation is considered to be closely related to the summer and autumn aridity conditions. Natural wetland vegetation represented by reed (*Phragmites australis*) communities and irrigated farms showed nearly the same responses in terms of seasonal vegetation activity.

From a geographical viewpoint, the proportion of the irrigated farms to natural wetland is quite high in the Syr Darya delta of the Aral basin; on the other hand, it stays at a low ratio, about one-sixth, in the Ili delta of the Balkhash. Most wetlands of the Syr Darya delta, as well as old deltas in the Kzrl-Orda region, have been converted into rice paddy fields, and natural wetlands are only observed at the newly emerged deltas that formed after the drastic shrinkage of the Aral Sea. In contrast, most of the wetland of the Ili River basin has retained a relatively natural condition. Two large irrigated farms were observed at the upper part of the alluvial fan of the Ili, but none was seen in the wet lowlands, where semi-natural conditions still exist.

Plant Succession after Desiccation of the Seabed

The drastic shrinkage of the Aral Sea meant the emergence of enormous areas of desiccated seabed, which is a possible source of salty sand storms around the coastal regions of the former Aral Sea. In reality, the series of upland plant succession, observed in Fig. 4, shows some probabilities of ecological impact mitigation by plant succession. Most of the wet and salty newly emerged seabed is soon to be covered by annual halophytes, such as *Salicornia* sp., followed by perennials and woody shrub species colonized on dry and salty sites. Black and white saxaul trees, *Haloxylon* spp., are the most important species in terms of firewood production of dry Central Asia; however, those species are not observed even 40 years after desiccation except in very limited areas. Saxaul trees

Fig. 4. Plant Succession on the Desiccated Seabeds of the Aral Near the River Mouth of the Syr Darya

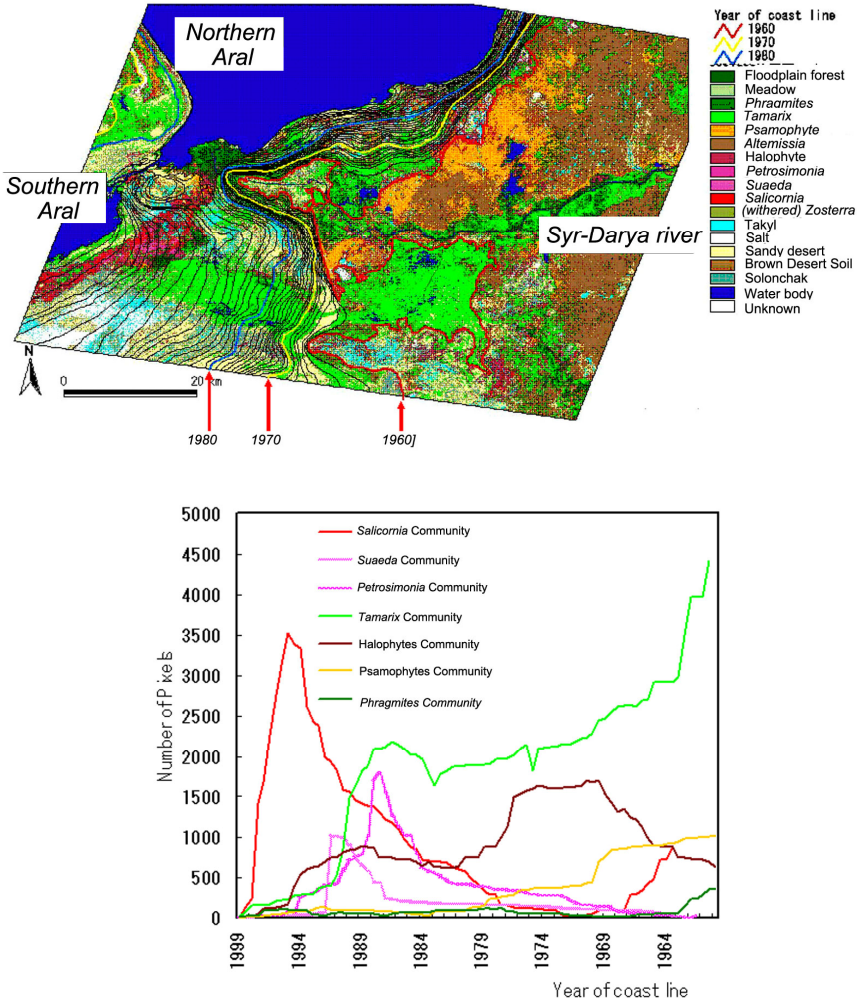
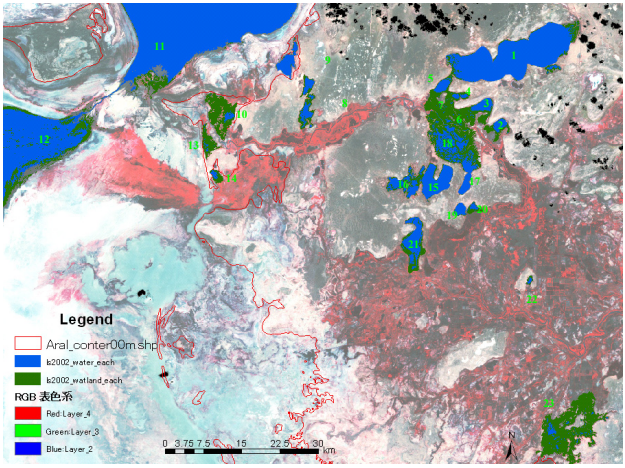


Fig. 5. Monitored Small Lakes and Marshes and Number of Observed White Pelicans in the Lower Syr-Darya Region in 2002



No	Lake	Obs.	Fisherman	Breeding
1	Lake Kamsrbas	0	0	0
2	Lake Laimkol	0	0	0
3	Lake Jaranasikol	0	0	0
4	Lake Kayaji	0	0	0
5	Lake Laikol	0	0	0
6	Lake Kuli 1	0	5＊	1
7	Lake Kuli2	0	0	0
8	Lake Tyusibas	0	0	0
9	Bay Bugun	0	0	0
10	Lake Karasyaran	1	4＊	1
11	Small Aral	4	10＊	1
12	Big Aral	0	10＊	1
13	Lake Bayanskoe	0	0	0
14	Lake Karrtama	0	0	0
15	Lake Akusyatau east	0	0	0
16	Lake Akusyatau west	0	0	0
17	Lake Karakol	0	1＊	1
18	Karakol Marsh	1	1＊	1
19	Lake Syamusikol 1	0	0	0
20	Lake Syamusikol 2	0	0	0
21	Lake Katankol	0	0	0
22	Lake Asikol	0	0	0
23	Bozgory Marsh		1＊	1

＊Observation of young bird

had been subject of overuse for firewood in the dry regions; and the absence of seed sources of saxaul trees and the seasonal west wind seem to be responsible for the prevention of the plant succession. The absence of the seed source is due to the overuse of saxaul trees, especially in the areas surrounding villages. Desiccated seabeds of the Aral, therefore, seem to be on the biased way of succession.

Pelican Habitat

There are small lake systems in the lower Syr Darya River delta before the river reaches the Aral Sea, and the lakes may play an alternative role to the Aral in terms of pelican habitat after the ecological crash of the fish population in the Aral Sea because of its excessive salinity. According to fishermen, those areas were a stable safe breeding habitat for pelicans before the tragedy. The drastic change in the water level of lakes in the territory with the shrinkage of the Aral and the fact that a colony of pelicans requires a large quantity of fish make a small lake with anthropogenic influences unsuitable for breeding. We monitored pelicans at the lower Syr Darya delta to clarify the suitability of the lake systems as a pelican habitat.

The results are shown in Figs. 5 and 6. Analyzing the data by logistic regression for the presence/absence of pelicans, it was proved that pelicans require a large lake for nesting, more than 18.1 km^2 to exceed the probability of 50%. Of course, dense reed communities and fish populations are also essential factors.

We also conducted a habitat survey in the Balkhash basin using satellite tracking of migration routes. We attached satellite telemetry transmitters to six pelicans of the species *Pelecanus onocrotalus* in 2002 at Lake Solbrak and 2003 at Lake Arakol in eastern Kazakhstan and tracked the migration route from summer to winter. The result of our investigation clearly identified that pelicans depend mainly on wetlands and water bodies with vegetation in the steppe and semi-arid regions for breeding, resting, and wintering. They are fragile and easily influenced by artificial water control in the upper streams and canals for irrigation. The pelicans had crossed the border of Kazakhstan, Uzbekistan, and Turkmenistan, and the distance of the migration route was approximately 800km. Accordingly, three international rivers, the Thu, Syr Darya, and Am Darya,

are considered to be very important resting places for breeding pelicans in Kazakhstan. Using the geographical data of migration, we analyzed the distribution of suitable habitats and areas for migration on the basis of satellite images of Terra/MODIS and a digital elevation model. The distribution of essential areas for migration between main habitats of the lower Ili River and Lake Shardara could be identified. As a result of our migration route study, the role of the corridor system of the wetland was shown to be important in addition to the breeding and wintering sites.

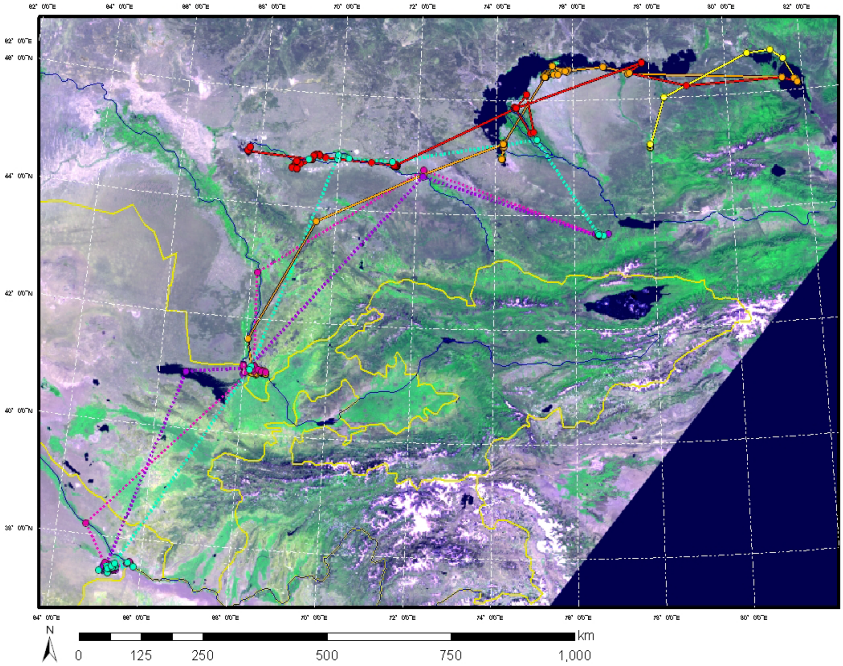
OVERALL DISCUSSION AND PROBLEMS TO BE SOLVED

By comparing the Aral and Balkhash, we can point out the importance of assessing an area's capacity for sustainable agriculture, which should be discussed from the viewpoint of landscape ecology, such as shifting mosaics and nature-oriented land use that respects sustainability.

The construction of the new Aral Sea dam supported by the World Bank seems to be a solution to save the Northern (Small) Aral by cutting off the larger Southern Aral. It is just like a "balanced contraction" in a company restructuring for survival in a severe economic depression. A preliminary survey of the effects of the dam on the ecosystems of the Northern Aral is quite favorable in terms of the restoration of its basic biological productivity. In fact, fish catches are reported to be improving significantly. However, it is noteworthy that the freshwater resources are not only for agricultural production or fishing resources but also for the wildlife habitat that makes an environment sustainable. Salinized soils could be leached and flashed by seasonal flooding in a natural wetland with vegetation, such as a reed community and tugai forest, which is an essential habitat for wildlife, including fish and pelicans. Each plant community may not be stable, but the vegetation mosaics are sustainable as a whole. The process, called shifting mosaics, makes the landscape heterogeneous.

We believe that pelicans, as the top predator, could be a symbol of the integrity of the wetland ecosystems of Central Asia; however, further scientific research is needed not only for biodiversity conservation but also for the optimized use of water resources. (1) Lake Balkhash may be the most important habitat for pelican breeding in the former Soviet

Fig. 6. A Satellite-tracked Migration Route of Dalmatian Pelicans from Their Breeding Site, Lake Solbrak, to Their Wintering Site, Lelif Reservoir, in 2002 and from Lake Arakol to the Shardara Reservoir in 2003, with Satellite Image Terra/MODIS (16-day composite: 29 Aug. to 13 Sep., R: band1, G: band2, B: band3)



Union; however, more intensive monitoring using helicopters is needed to evaluate the status as a species. (2) The kind of fish that pelicans eat is not clear at present. Stable isotope analysis, a powerful tool, should be used to clarify the web of life in the Aral. (3) Landscape ecological patterns and processes of the Ili River mouth could be a good reference for land and water use of the Aral and Syl Darya. The relationship of seasonal ecological processes to fish reproduction and its sustainable use need to be explored. (4) We have just started the satellite tracking of pelicans and have obtained important new information on their migration route. However, more detailed tracking data are needed to establish

a dynamic and reliable habitat model for pelicans in an environmental assessment in relationship to water resource management. Such studies are expected to contribute to the sustainable use of fresh water use of Central Asia by clarifying the landscape ecological dynamics of arid but wet and unique ecosystems.

REFERENCES

Auezov, E. M., "Data on Endangered and Rare Birds of the Lakes of the Tengiz-Kurgaldzhino Depression and the Turugai Depression," *Rare and Endangered Animals and Birds of Kazakhstan,* Alma-Ata: Nauka, 131–134, 1997.

Breckle, S. W., S. Scheffer, and W. Wucherer, "Halophytes on the Dry Sea Floor of The Aral Sea," in Breckle, Siegmar-W., Maik Veste, Walter Wucherer eds., *Sustainable Land Use in Deserts*, Berlin: Springer, 139–146, 2000.

Prynn, D., "The Caspian Tiger: A Lesson from History," *Marwell Zoo News,* 116:10–11, 2003.

Environment News Service [http://www.ens-newswire.com/ens/mar2007/2007-03-16-01.asp], 2007.

Horikawa, M., Y. Morimoto, Y. Natuhara, and K. Pachikin, "Monitoring of Vegetation Change of Syr Darya Delta and the Bottom-dried Aral Sea Area Using SPOT Satellite Data," *J. Japanese Institute of Landscape Architecture (JILA)*, **64**, 5:808–811, 2001. (in Japanese)

Horikawa, M., and Y. Morimoto, "Quantitative Evaluation of Vegetation Fluctuation with the Shrinking of Aral Sea Using the Satellite Image of NOAA/AVHRR," *J. Japanese Institute of Landscape Architecture (JILA)*, **63**, 5:779–782, 2000. (in Japanese)

Horikawa, M., and Y. Morimoto, "Ecotope monitoring of the Syr Darya Delta for a Scenario Study of the Aral Crisis," *Bulletin of the International Association for Landscape Ecology-Japan*, **5**, 2:41–45, 2000. (in Japanese)

Markov, D. V., "Notes on *Pelicanus* and Cormorants of the Aral Sea," *Fish-eating Birds and Their Significance in the Fishing Industry*, Moscow: Nauka, 156–165, 1965.

Morimoto, Y., M. Horikawa, and Y. Natuhara, "The Pelican Scenario for Nature Restoration of Aral Sea Wetland Ecosystems," *Landscape and Ecological Engineering* **1**, 1:85–92, 2005.

Morimoto, Y., and A. Morimura, "Landscape Ecological Considerations on

the Aral Sea Crisis and the Vegetation Dynamics," *Jpn. J. Revegetation Tech.* 22, 3:181–189, 1997.

Ogar, N., "Vegetation Dynamics of on the Syr Darya Delta and Modern Land Use," in Breckle, Siegmar-W., Maik Veste, Walter Wucherer eds., *Sustainable Land Use in Deserts*, Berlin: Springer, 74–83, 2000.

Ohsawa, M., "Montane Evergreen Broad-leaved Forests of the Bhutan Himalaya," in M. Ohsawa, ed., *Life Zone Ecology of the Bhutan Himalaya*, Chiba: Chiba University, 89–156, 1991.

Stautman, Y. E., and Y. V. Stepanov, "Swan and Pelican Numbers on the Main Water Bodies of Kazakhstan and Measures to Conserve Them," *Rare and Disappearing Animals and Birds of Kazakhstan*, Alma-Ata: Nauka, 221–228, 1977.

Volkov, Y. N., "Aerial Counts of Numbers of Colonial Birds on the Lakes of Central Kazakhstan," *Study and Conservation of State Reserve Species*, Alma-Ata: Nauka, 40–42, 1984.