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5 Aral Sea, Uzebekis tan and Kazakhstan

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Classification

International: The Aral Sea is one of seven large continental water bodies in central Asia, the others being the Caspian Sea and lakes Balkhash, Issyk-Kul, Chany, Alakul and Tengiz (Aladin & Plotnikov 1993).
IUCN Habitats Classification Scheme (Version 3.0): 5. Wetlands (inland) / 5.14 Permanent Saline, Brackish or Alkaline Lakes

Ecosystem Description

Characteristic native biota

The characteristic native biota of the Aral Sea includes a unique combination of freshwater and saltwater assemblages of free-living and benthic aquatic biota as well as associated wetland vegetation and bird assemblages (Aladin & Potts 1992). For example, a biogeographic analysis of Aral invertebrates suggested that 17% were of Caspian origin, 78% were of freshwater or saline water continental origin and 5% were of Mediterranean or oceanic origin (Yablonskaya 1974). Aladin & Potts (1992) compiled lists from various surveys and estimated the sea's biota to include 20 species of fish, 195 species of free-living invertebrates and 71 species of parasites, 12 species of higher plants and 82 species of lower plants. Williams and Aladin (1991) remark that the Aral Sea biota is neither diverse or productive.

The Aral phytoplankton consisted mostly of diatoms, flagellates and blue-green algae, with biomass fluctuating from 0.5 to 2.6 $g.m^{-3}$ (Aladin & Potts 1992). Species richness was greatest in the estuaries of the major rivers and lowest in the most saline sites. Only diatoms were common in the open sea, with *Actinocuclus ehrenbergii* var. crassa the dominant species present in densities of more than 1 million per cubic metre. Zooplanktonic biomass averaged 150 $mg.m^{-3}$, with higthest values in the shallow coastal waters. Common zooplankton in the open sea include: cladocerans *Podonevadne camptonyx*, *Evadne anonyx*, *Moina mongolica*, *Ceriodaphnia reticulata* and *Alona rectangula*; copepods *Arctodiaptomus salinus* and *Mesocyclops leuckarti*; rotifers *Synchaeta vorax*, *Keratella tropica* and *Brachionus plicatilis*; and mollusc larvae *Dreissena* and *Hypanis* spp. (Aladin & Potts 1992). Of these, *Arctodiaptomus salinus* was by far the most common, accounting for more than three-quarters of the zooplanktonic biomass. Several species of zooplankton were introduced to the sea during the 1960s (Aladin & Potts 1992).

The benthic flora of the Aral Sea consisted of angiosperms, green and red algae and charophytes, with species composition varying with sediment type and depth. The most common species include the angiosperm *Zostera nana*, the green algae *Polysiphonia violacea* and *Vaucheria dichotoma*, and the charophyte *Tolypella aralica* (Aladin & Potts 1992).

The benthic biomass of the Aral Sea averaged 23 $g.m^{-2}$ and was dominated by molluscs (Aladin & Potts 1992). The benthic macro-invertebrates include bivalve molluscs *Dreissena polymorpha* var. *aralensis*, *D. polymorpha* var. *obtusecarinata*, *D. caspia* var. *pallasi*,*Hypanis* *minima* var. *minima*, *H. minima* var. *sidorov*; oligochaete worms *Nais elengui* and *Paranais simplex*; ostracods *Cyprideus torosa*; amphipods *Dikerogammarus aralensis*; and insect larvae *Chironomus* and *Oecetis*. The Aral crustacean fauna includes some species of marine origin, such as *Evadne anonyx* and *Podonevadne camptonyx,* while others, such as *Cercopagispengoi aralensis,* derived from freshwater ancestors (Aladin 1995). Several species of crustacea and molluscs were introduced to the sea during the 1960s (Aladin & Potts 1992).

The Aral Sea fish fauna included bream (*Abramis brama* var. *orientalis*), carp (*Cyprinus carpio* var. *carpio*), Aral roach (*Rutilus rutilus* var. *aralensis*), Aral shemaya (*Chalcalburnus chalcoides*), zander (*Stizostedion lucioperca*), perch (*Perca jluviatilis*), ruffe (*Acerina cernua*), the Aral spiny sturgeon (*Acipenser nudiventris*), Aral sea trout (*Salmo trutta* var. *aralensis*), wels (*Silurus glanis*), pike (*Esox lucius*), and the Aral stickleback (*Pungitius platigaster* var. *aralensis*) (Aladin & Potts 1992). In addition to the twenty native species, fifteen additional species of fish were successfully introduced to the Aral Sea between 1920 and 196,1 including the Caspian sturgeon (*Huso huso*), the Caspian shad (*Alosa caspia*), the Baltic herring (*Clupea herengus membras*), grass carp (*Ctenopharyngodon idella*), round goby (*Pomatoschistis caucasicu*), monkey goby (*Neogobius melanostomus oficinus*), sand goby (*Neogobius juciatilis pallasi*), atherines (*Atherinus*), pipe-fish, and the Black Sea flounder (*Platichthys flesus* var. *lulscus*) (Aladain & Potts 1992). The native and introduced fish supported a fisheries industry with an average annual catch of 5 $kg.ha^{-1}$ reaching a maximum total annual catch for the whole sea of 44,000 tonnes, however the introductions did not significantly increase the annual fish catch (Aladin & Potts 1992).

Extensive reedbeds dominated by *Phragmites australis* lined hundreds of kilometers of the Aral Sea shoreline and were extensive in the river deltas, particularly in the south. The reedbeds, together with tugay woodlands in the river deltas and lower floodplains, provided breeding and foraging habitats for a diverse assemblage of birds. Other species forage in the sea itself, including the Dalmatian Pelican (*Pelicanus crispus*) and Great White Pelican (*P. onocrotalus*). These and other waterbirds are important dispersal vectors for planktonic biota and other aquatic taxa (Boomer et al. 1996). The total bird fauna of the sea and associated wetlands has been estimated at 319 species (Micklin & Aladin 2008).

Abiotic environment

The Aral Sea, the fourth largest continental water body in the world, occurs in a large topographic basin in central Asia (Fig. 1). It is fed by two major rivers, the Syr Dar'ya and Amu Dar'ya, which originate in the northern and western Himalayas and have a combined catchment area of more than 1.5 million km^2. In 1960, the sea covered 67,500 km^2, exceeding 20 m depth across about one-third of its area and 50 m at its deepest point (Boomer et al. 2000). Hydrologically, the sea level was approximately stable varying less than one meter during 1911-1960. During this time inflows balanced net evaporation, each approximately 56 $m^3.yr^{-1}$, with salinity approximately 10 $g.l^{-1}$ (Micklin 2006). Earlier observations suggest a longer period of sea level stability, with variations of less than 4.5 m since the mid-eighteenth century until the 1960s (Bortnik 1996). Over longer time scales, there is evidence of more substantial water-level fluctuations of up to 45 m since the late Pleistocene. Boomer et al. (2000) describe the geomorphological evolution of the sea from the early Pleistocene and map inferred fluctuations in its extent over the past 10,000 years. Since its initial filling, the Aral Sea has periodically been connected with the Caspian Sea via the Sarykamysh Depression and the Uzboi Channel to the southeast, and this has been important for colonisation of marine biota (Boomer et al. 1996, 2000).

Figure S5. 1. Aral Sea oblique view taken from the north by NASA Space Shuttle mission STS-51-F on 6th August 1985. Source: http://en.wikipedia.org/wiki/Aral_Sea from http://eol.jsc.nasa.gov/sseop/EFS/photoinfo.pl?PHOTO=STS51F-36-59

Distribution

The Aral Sea is centred on 45°N and longitude 60°E, straddling the border between Uzebekistan and Kazakhstan in central Asia. In 1960 it was estimated to cover a contiguous area of 67,500 km^2. At the present time three lakes occupy the former sea bed with a combined area of 17,000 km^2 (Fig. 2).

Figure S5. 2. Location of the Aral Sea on the border between Uzbekistan and Kazakhstan in central Asia. Source: World Lakes (http://www.worldlakes.org)

Key processes and interactions

Benthic vegetation and phytoplankton provide the primary productivity that sustains the characteristic assemblages of zooplankton, benthic macro-invertebrates and fish within the sea (Fig. 3). Productivity is promoted by nutrient inflow through the riparian and delta ecosystems connected to the sea (Aladin & Potts 1992, Micklin 2006). Hydrological connectivity also permits movement of freshwater organisms between these ecosystems (Fig. 3). Fringing reedbeds and riparian vegetation also contribute to primary productivity and provide breeding habitat for a variety of birds and foraging resources for mammals (Aladin & Potts 1992, Micklin 2006). Waterbirds, including migratory species, that consume fish and aquatic invertebrates from the sea play important roles in dispersing other organisms and transferring nutrients between the Aral Sea and other wetlands in the region (Boomer et al. 1996).

River inflow regulates the volume and water chemistry of the Aral Sea, and hence the relative abundance of freshwater and marine biota in the brackish ecosystem (Williams & Aladin 1991). The sea expands when inflows from rivers exceed net evaporative loss and contracts when inflows fail to compensate evaporative loss (Micklin 2006). When sea levels are high, salinity levels are low and freshwater biota predominate. As sea levels fall, the waters become more saline and saltwater biota predominate. Extreme drying results in transition of the brackish Aral Sea ecosystem into hypersaline lakes and desert (Fig. 3).

Climate and the human activity in the catchment of the Aral Sea influence its hydrological dynamics by regulating water inflow (Fig. 3). Regression of the sea corresponds with episodes of climatic drying and water extraction (Boomer et al. 2000, Micklin 2006). Drying of the sea may also have feedback effects on regional climate warming (Khan et al. 2004).

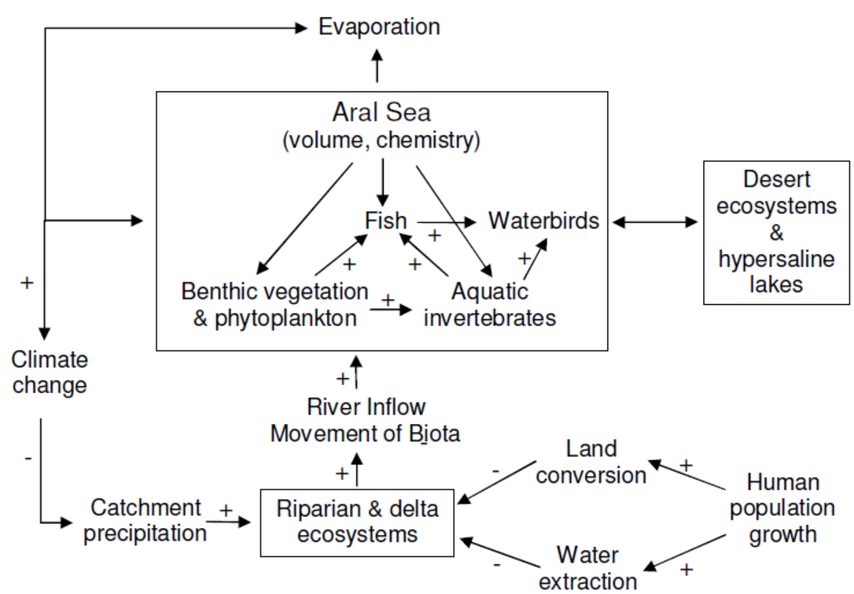

Figure S5. 3. Cause-effect model of ecosystem dynamics for the Aral Sea showing positive (+) and negative (-) environmental and anthropogenic influences on ecosystem processes and components, and interactions with neighbouring ecosystems. Feedbacks from the Aral Sea ecosystem to the regional human population are not shown.

Threatening Processes

The major threat to the Aral Sea ecosystem is desiccation and salinisation caused primarily by water extraction to support expansion of irrigated agriculture in the river valleys and deltas of the Syr Dar'ya and Amu Dar'ya and the adjacent desert (Micklin 1988, Micklin & Aladin 2008). Although irrigation has been practiced in the region for more than 5,000 years, the area under irrigation tripled between 1949 and 1986 from 2.14 to 6.41 million ha (Micklin 1988, Boomer et al. 2000), and by 2007 had expanded to 7.9 million ha (Micklin 2006). As irrigation expanded into the desert, more water was lost to evaporation than when irrigation was confined to the river deltas prior to 1950. This reduced inflow to the sea from 56 $m^3.yr^{-1}$ before 1960 to 5 -15 $m^3.yr^{-1}$ during 1970 - 2006, resulting in a substantial deficit to net evaporation. Consequently, the sea dried up throughout much of its area, fragmented into several separate lakes and the salinity of the remaining water increased by more than an order of magnitude (Micklin 2006). The hydrological changes precipitated a dramatic loss of invertebrate fauna, fish and plants from the sea. As well, the reedbeds of the sea shorelines have disappeared and the tugay woodlands and reedbeds of the river deltas have contracted to one-third of their area, resulting in a major diminution of the mammalian and avian fauna dependent upon the vegetation. Micklin and Aladin (2008) summarise the changes between 1960 and the mid 1990s as follows: marsh vegetation contracted from 100,000 ha to 15,000 ha; fish species declined from 32 to six; bird species declined from 319 to 160; and mammal species declined from 70 to 32. While some of these species remain in the reduced river systems or in other regions, others are presumed extinct (Aladin & Potts 1992, Micklin 2006). Drying of the sea also resulted in collapse of shipping and fisheries industries (Fig. 4), reducing dietary variety and increasing malnutrition. Wind-born dust and aerosols from the dry sea floor are also associated with major public health problems including respiratory illnesses, cancer, and digestive disorders, liver and kidney ailments, eye problems and elevated infant mortality (Micklin & Aladin 2008).

Historically, introduced species also posed a threat to the native biota, significantly altering the composition of fish, zooplankton and macro-invertebrate assemblages (Aladin & Potts 1992). However, these effects have largely been overriden by the impacts of desiccation and salisation, and many of the introduced species have been eliminated, along with the native biota.

Figure S5. 4. Former bed of the Aral Sea transformed to a halophyte herbfield. Ecosystem collapse triggered economic ruin for shipping and fishing industries. Source: http://en.wikipedia.org/wiki/File:Aralship2.jpg

Ecosystem collapse

Much of the characteristic native biota recorded in the Aral Sea prior to 1960, including fish, zooplankton, maco-invertebrates and plants, has been eliminated from the ecosystem as their habitats became too dry or too saline to support persistence of viable populations (Micklin 1988, Micklin & Aladin 2008). The loss of biota, and hence collapse of the ecosystem, coincided with shrinkage of the water body and its fragmentation into several separate lakes (Fig. 5).

Thresholds of collapse were defined byexamining the chronology of events. Aladin & Potts (1992) identified three periods of decline. The first occurred during 1960-68 when the volume of the sea declined by less than 10% and salinity increased marginally from 10 to 11 g.l^{-1}. Declines in the abundance of phytoplankton and native fish during this period were attributed primarily to introductions of plankton-eating copepods and fish in the 1960s, however, it appears that few if any native species were lost from the ecosystem (Aladin & Potts 1992).

The second period of decline occurred during 1970 -1975, when the sea volume declined by c. 20% and salinity increased from 11 to 14 g.l^{-1} (Table 1). The decline in river inflows that caused these changes reduced influx of nutrients and hence productivity, causing a 3- to 5-fold reduction in phytoplankton biomass and a compositional shift from brackish and freshwater taxa to marine euryhaline taxa (Aladin & Potts 1992). At the beginning of this period the diversity of ostracods had declined from 11 to one species (Boomer et al. 1996), and bythe mid-1970s, benthic annelids declined from seven to one species, and the diversity of benthic arthropods declined from 27 to seven species (Williams & Aladin 1991). Salinization and drying of spawning grounds in the shallow coastal waters initially affected juvenile fish, and by the mid-1970s had slowed growth rates, increased mortality and largely inhibited breeding in adults (Aladin & Potts 1992). Between 1976 and 1985, the Aral Sea biota was relatively stable (Aladin & Potts 1992), even though the sea volume declined by a further 45% and salinity rose from 14 to 22 14 g.l^{-1} (Table 1) and commercial fishing had ceased by 1981.

Figure S5. 5. Comparison of Aral Sea extent between 1985 (left) and 2011 (right) showing extensive drying and fragmentation of the water body. Source: http://en.wikipedia.org/wiki/File:Aral_Sea_1989-2008.jpg

The third period of decline occurred during 1987 - 1989, when the Aral Sea fragmented into two separate water bodies, a northern one fed bySyr Dar'ya and a southern one fed byAmu Dar'ya. By 1989, salinity had tripled to 30 g.l^{-1}, the total number fish species had declined from 32-35 (in 1960) to 10, with only four of the 20 native species remaining, and only 14 invertebrate fauna species were recorded (cf. 164 species in 1960).

Since 1990, the northern and southern water bodies have followed different trajectories (Micklin 2006). The southern water body, continued to decline in volume, with salinity reaching 100 g.l^{-1} and all fish species disappearing by 2006 (Table 1). The northern waterbody received significant recharge due to high rainfall in the Syr Dar'ya catchment in 2002, and in 2005, a weir was constructed to regulate outflow, followed by another significant recharge event. This reduced salinity levels to 12 g.l^{-1} by 2005 and 10 g.l^{-1} by 2007 (Micklin & Aladin 2008). In response, numerous fish species recolonised the water body from refuges in the Syr Dar'ya and its delta wetlands, with the total number of species reaching 13 by 2005 and 16 by 2007, including fifteen of the twenty native species, albeit in different relative abundances.

From the above chronology, it was assumed that the Aral Sea ecosystem collapsed between 1976 and 1989 during either the second or third periods of decline described by Aladin & Potts (1992), as substantial losses of characteristic biota and changes in ecological character occurred during these times. The original brackish ecosystem was replaced by several novel ecosystems, including halophytic and xerophytic shrublands and herbfields on the dry sea bed, hypersaline lakes in the south and a new brackish ecosystem in the north comprising a subset of the original native biota and some introduced biota. Collapse thresholds in distributional and functional variables were therefore set based on their values during 1976 - 1989. Thus, for assessing declines in distribution under criterion A, it was assumed that the ecosystem collapsed when sea surface area declined below 55,700 to 39,734 km^2.

For assessing environmental degradation under criterion C, it was assumed that the ecosystem collapsed when sea volume declined below 364 - 763 km^3 or when average salinity increased to 14 - 30 g.l^{-1}. Preliminary investigations based on analyses of ostracod assemblages and chemical analyses of molluscs and ostracod shells from two short cores and one section from the shores of the Aral Sea indicated that salinity levels of 30 g.l^{-1} had not been attained during the period represented by the cores (Boomer et al. 1996), suggesting that these levels were outside the natural range of ecosystem variation.

For assessing disruption to biotic processes under criterion D, it was assumed that collapse occurred when the detectable number of originally native (i.e. 20 species in 1960, Aladin & Potts 1992) fish species fell below 4 – 10 species. The commercial catch of fish was assumed to be a proxy for total fish abundance, which had fallen to 10,000 tonnes by 1977 and zero by 1980. It was therefore assumed that ecosystem collapse was coincident with fisheries collapse. Although more data are available for fish than other taxa, Aladin (1995) studied the salinity tolerance of cladoceran crustaceans in the family Podonidae experimentally, showing that the upper limits of survival for the four Aral species varied from 26 to 30 g.l^{-1}. A collapse threshold was therefore set at 0-1 species in this group. Similarly, collapse thresholds could also be set for the number of detectable ostracods (1 species), benthic annelids (1 species) and benthic arthropods (4 – 7 species), as these groups also declined rapidly with salinisation of the sea.

ASSESSMENT

Summary

Criterion	A	B	C	D	E	overall
subcriterion 1	CO	VU	CO	CO	NE	CO
subcriterion 2	CO	LC	CO	CO		
subcriterion 3	CO	VU	CO	CO		

Criterion A

Current decline: Changes in the distribution of the Aral Sea were assessed using estimates of sea surface area from remote sensing (Fig. 6). Between 1960 and 2005, the surface area declined from 67,499 km^2 to 17, 382 km^2, passing the threshold of collapse (39,734 - 55,700 km^2) during 1976 - 1989. The status of the ecosystem under criterion A1 is therefore Collapsed.

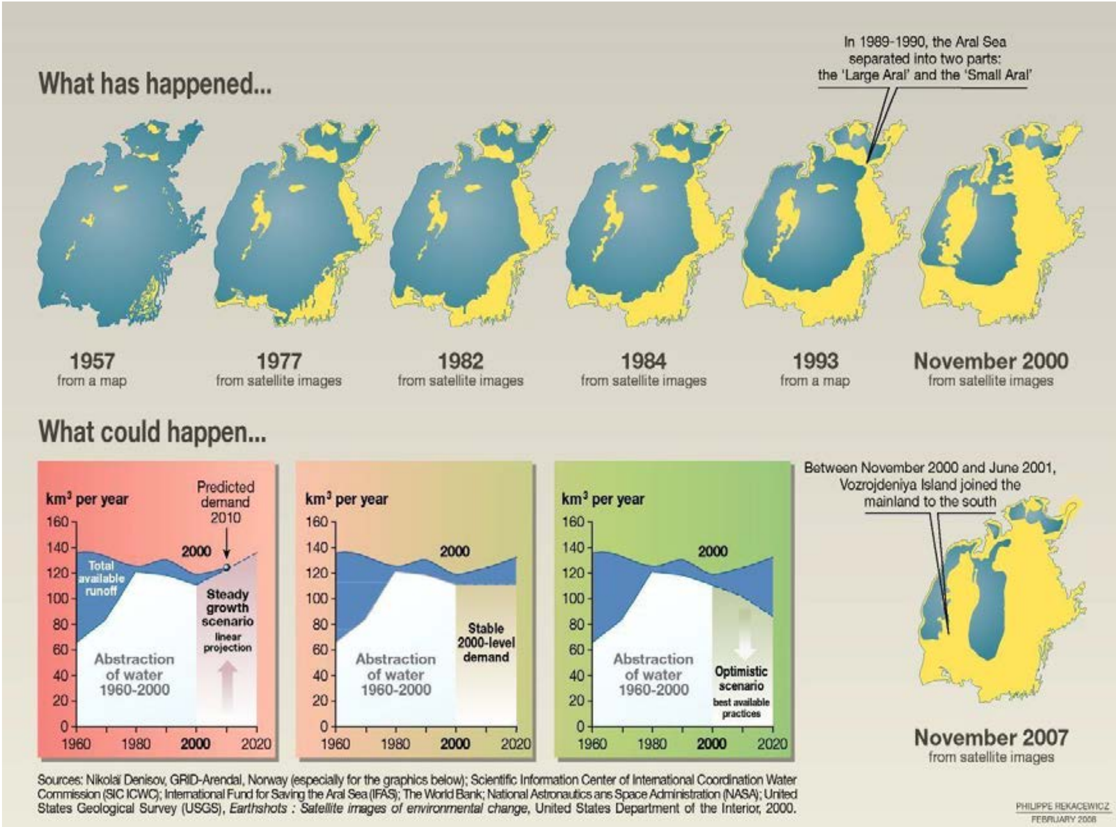

Figure S5. 6. Changes in surface area of the Aral Sea over 50 years 1957 to 2007. Source: UNEP (2008).

Future decline: Various projections exist for a range of hydrological restoration scenarios for the Aral Sea (Aladin et al. 2005). Hydrological restoration of the northern water body is considered feasible, assuming a modest inflow of 7 $km^3.yr^{-1}$ from the Syr Dar'ya and regulation of outflow by a dam constructed on Berg's Strait, which connects the northern and southern water bodies (Aladin et al. 2005). However, reversal of collapse by increasing water surface area above the collapse threshold is unlikely for two reasons. Firstly, the northern water body accounts for only a small fraction of the total area of the former sea, even when completely full it covers 5650 km^2 (Aladin et al. 2005), some 34,000 km^2 less than the lower bound of the collapse threshold. Hence, to exceed the collapse threshold, a large quantity of additional water would also need to be maintained in the southern water body. This is considered implausible, given the increased size of the regional population within the Amu Dar'ya catchment and the higher evaporation rates under a warming climate, compared to the pre-collapse era (Boomer et al. 2000; Aladin et al. 2005; Micklin 2006; Micklin & Aladin 2008). Secondly, even though water may be restored to the northern water body, the evidence supports its interpretation as a novel ecosystem, given that only a subset of the pre-collapse native biota are returning due to extinctions (Micklin 2006), that these are so present in different proportions and that the re-establishing biota includes species that were not present in the native biota of the original system (Aladin & Potts 1992; Micklin 2006). The status of the Aral Sea ecosystem under criterion A2 is Collapsed.

Historic decline: The Aral Sea was hydrologically stable since at least the mid eighteenth century (Bortnik 1996). Hence the decline in distribution over the historical time scale is the same as the decline over the past 50 years, exceeding the threshold of ecosystem collapse. The status of the ecosystem under criterion A3 is therefore Collapsed.

Criterion B

Extent of occurrence: The current distribution of the Aral Sea based on the surface area of open water depends on the status of the southern water body. In recent years, the eastern arm of this water body has either been filled with a shallow depth or water or dry. The extent of occurrence of the Aral Sea was estimated as 25,000 - 40,000 km^2, based on two minimum convex polygons enclosing all occurrences, respectively assuming the eastern arm was filled with water (upper bound) and assuming it was dry (lower bound). There are continuing declines in distribution (see criterion A), plausible threats and the sea occupies 1 - 2 locations, depending on whether the northern and southern water bodies are interpreted as independent locations. The status of the ecosystem is therefore Vulnerable under criterion B1a,b,c.

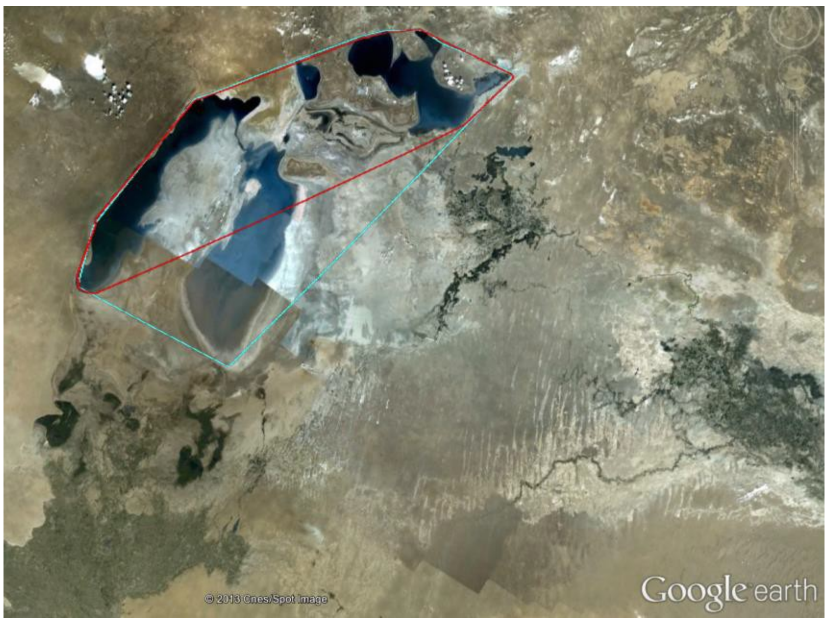

Figure S5. 7. Minimum convex polygons representing lower (red) and upper (blue) bounds of the current extent of occurrence of the Aral Sea surface waters.

Area of occupancy: Depending on whether the eastern arm of its southern water body is filled with water, the Aral Sea occupies 70 - 155 10 × 10 km grid cells. The status of the ecosystem is therefore Least Concern under criterion B2.

Number of Locations: The Aral Sea occupies 1 - 2 locations, depending on whether the northern and southern water bodies are interpreted as independent locations. The most severe plausible threat to the Aral Sea is continued drying and associated salinisation. The ecosystem is prone to severe threats, such as clearing and drought, such that is may become, or may already be Critically Endangered. It therefore qualifies for Vulnerable status under criterion B3.

Criterion C

Current decline: Sea volume and average salinity were identified as appropriate variables for assessing environmental degradation under criterion C. Total sea volume fell below the bounded collapse threshold between 1976 and 1989, and continued to decline in subsequent years (Fig. 8). Average salinity exceeded the collapse threshold during the same time. After fragmentation of the sea, the salinity of the southern water body continued to increase, while the salinity of the northern water body declined, eventually below the collapse threshold (Fig. 9). However, at this stage, both the northern and southern water bodies were interpreted as novel ecosystems, and the data for the northern water body this were not interpreted as a reversal of collapse or a fluctuation in salinity for reasons discussed under criterion A. In addition, the salinity levels recorded in 1990 are higher than any historical values recorded in the history of sea sediments (Boomer et al. 2000), and therefore outside the natural range of variation in the ecosystem. The extent of degradation estimated by both sea volume and average salinity was 100% of the ecosystem distribution. The status of the ecosystem was therefore Collapsed under criterion C1.

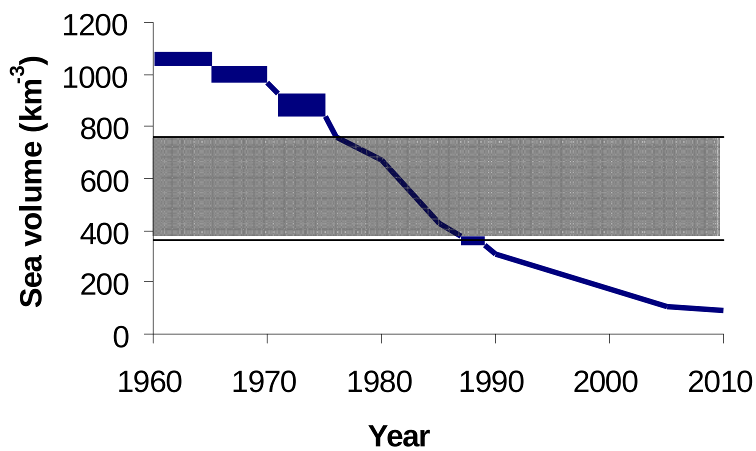

Figure S5. 8. Trends in total volume of the Aral Sea, relative to a bounded threshold of ecosystem collapse. Data compiled from Williams & Aladin (1991), Aladin (1995) and Micklin (2006).

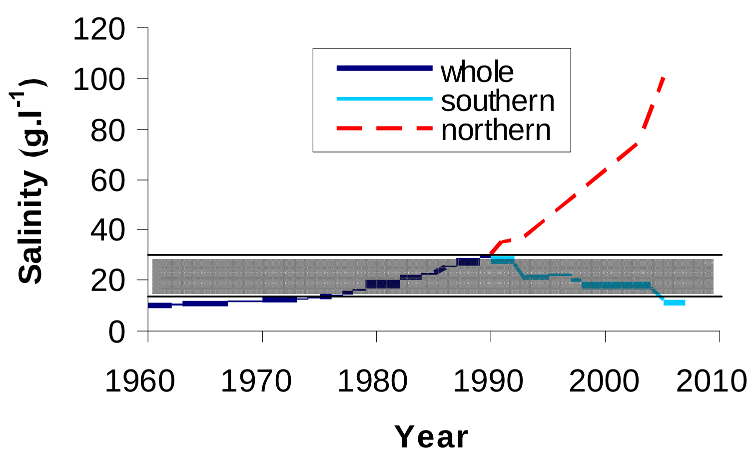

Figure S5. 9. Trends in average salinity of the Aral Sea, relative to a bounded threshold of ecosystem collapse. Data compiled from Aladin (1995), Aladin et al. (2005) and Micklin (2006).

<u>Future decline</u>: Various projections exist for a range of hydrological restoration scenarios for the Aral Sea (Aladin et al. 2005). For the southern water body, sea volume is projected to continue declining and salinity is projected to continue rising, possibly as high as 150-200 $g.l^{-1}$.
For the northern water body, sea volume and salinity are projected to remain relatively stable, so long as inflows are maintains above 7 $km^3.yr^{-1}$ and outflows are regulated as described under

criterion A (Aladin et al. 2005). However, reversal of collapse by increasing sea volume or reducing salinity in the northern water body is unlikely for reasons discussed above under criterion A. The status of the ecosystem under criterion C2 is therefore Collapsed.

Historic decline: The Aral Sea was hydrologically stable since at least the mid eighteenth century (Bortnik 1996). Hence environmental degradation estimated from sea volume and salinity over the historical time scale is the same as the decline over the past 50 years, exceeding the thresholds of ecosystem collapse. The status of the ecosystem under criterion C3 is therefore Collapsed.

Criterion D

Current decline: Different biotic variables showed slightly different rates of decline. The commercial fish catch had ceased by1981 (Fig. 10), although as many as 15 native species may have remained extant at that time (Fig. 11), albeit in low abundance and unable to reproduce. The number of native fish declined to four species by 1989 and only one remained in 1992. Although about 70% of the native fish fauna had recolonised the northern Aral water body from the delta of the Syr Dar'ya by 2007 (Fig. 11), the catch has recovered to only 5% of pre-decline levels and includes a substanital proportion of introduced species (Black Sea perch). The Southern water body remains without fish. The fisheries data therefore suggest that the ecosystem collapsed between 1981 and 1989.

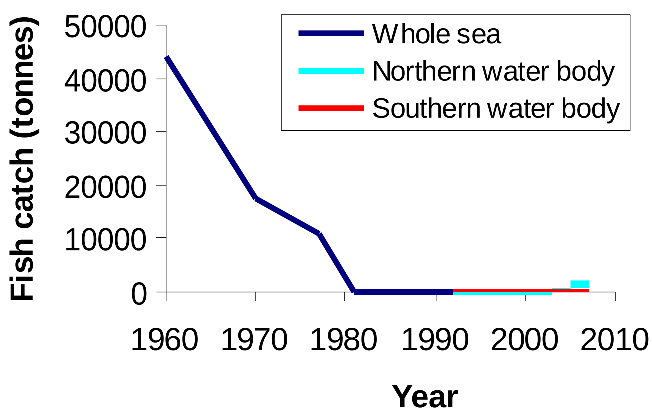

Figure S5. 10. Total commercial fish catch in the Aral Sea before and after its fragmentation into separate northern and southern water bodies. Threshold of ecosystem collapse assumed to be a catch of zero tonnes. Data compiled from Aladin & Potts (1992), Micklin (2006) and Micklin & Aladin (2008).

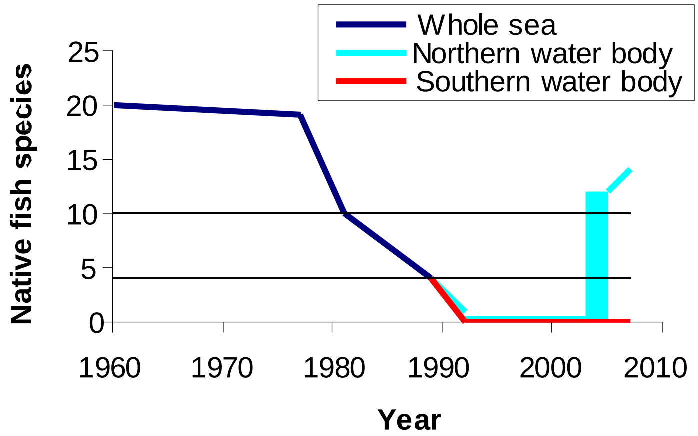

Figure S5. 11. Number of native fish in the Aral Sea before and after its fragmentation into separate northern and southern water bodies. Threshold of ecosystem collapse shown in grey. Data compiled from Aladin & Potts (1992), Micklin (2006) and Micklin & Aladin (2008).

The ostracod diversity had reached a collapse threshold of one species by 1970 (Boomer et al. 1996), while benthic annelids and arthropods had reached their thresholds of collapse (one and seven species, respectively) by 1976 (Williams & Aladin 1991). Podonod cladocerans had reached their threshold of collapse (one species) by 1989 (Aladin 1995). Collectively, the biotic data support the status of Collapsed under criterion D1 and suggest that collapse occurred during the period 1970 - 1989.

<u>Future decline</u>: There are no quantitative projections of future trends for any of the biotic variables. Although some further recolonisations and increases in fish catch are expected in the northern water body, some of the original biota is presumed extinct. The larger southern water body is expected to remain dry and hypersaline and hence unsuitable for the majority of the characteristic native biota of the former Aral Sea (Aladin et al. 2005, Micklin & Aladin 2008). Hence a reversal of ecosystem collapse is very unlikely during the next 50 years, even though biodiversity of the novel ecosystem in the northern water body may continue to increase if inflows are maintains above 7 $km^3.yr^{-1}$ and outflows are regulated as described under criterion A (Aladin et al. 2005). Hence, the status of the Aral Sea under criterion D2 is Collapsed.

<u>Historic decline</u>: The Aral Sea was relatively stable biologically prior to 1960 (Aladin & Potts 1992). Hence disruption to biotic processes and interactions estimated from the diversity of vertebrate and invertebrate taxa is the same over the historical time scale as the decline over the past 50 years, exceeding the thresholds of ecosystem collapse. The status of the ecosystem under criterion D3 is therefore Collapsed.

Criterion E

No quantitative analysis has been carried out to assess the risk of ecosystem collapse for Aral Sea. Hydrological models developed by Aladin et al. (2005) could potentially contribute to such an analysis. Until this work is done, the status of the ecosystem is therefore Data Deficient under criterion E.

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