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Subject:	Fw: Agonizing Coastal Sea Ecosystems
Date:	Thursday, October 06, 2011 8:44:10 PM

Dear Coleagues,
Due to malfaction of my computef, I send again this publication.

Cordially,

M.Rozengurt

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Agonizing Coastal Sea Ecosystems: Understanding The Cause; placing the blame!

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Abstract.

The dissection of rivers by dams has distorted interaction of coastal ecosystems and led to the formation of "impounded seas " on a global scale**.**

All the above belies the statements claiming that it is possible to restore historical habitats of impounded coastal ecosystems despite the fact that their unnatural, broken continuum has nothing in common with the history of their evolution should be considered as reductio ad absurdum.

Introduction. Consideration for river-estuaries-coastal sea management.

Coastal sea ecosystems used to be the world's most productive basins. They supported migration routes, spawning, nursery, and feeding grounds for a reach diversity of valuable fish and shellfish. Their properties and survival were based on four fundamental processes: 1) stochastic fluctuations of unimpaired runoff; 2) dynamic equilibrium of water and salt balance; 3) ecological continuity, and 4) biological tolerance. Their natural regime peculiarities sustained life in coastal embayment for millenniums, and concomitant enhancement of coastal seas. Spring runoff was the lifeblood of ecosystems. Normally the stronger the flooding the more kinematics' energy is available to regulate water and salt exchange between an estuary and coastal sea, or to enhance advection, horizontal and vertical mixing, and circulation of estuarine and marine waters as well as sea biochemical characteristics. Spring flooding used to serve as a physical barrier to repulse excessive saltwater intrusion into estuaries and deltas, and flash out natural or man-made contaminants. In other words, a natural spring inflow energy tended to maintain the regime balance through outflows to seas as required by the first law of thermodynamics (Fig.1). Suffice to say, that the powerful frictional drag could entrain up to 10 to 100 times volume of marine waters than that of flood itself. In this case, the enrichment of seas with thousand tons of oxygen, inorganic and organic matters took place. Riverine or estuarine plumes that participate in these processes can be seen between mixed and fully marine waters of many kilometers from river mouths or straits. Moreover, a part of the energy outflow transfer is linked to the dispersion into an unavailable form of energy as required by the second law. But most important was its ability to maintain essential equilibrium of food chain and vitality of numerous fresh and marine waters' organisms for millennia (Rozengurt, 1974).

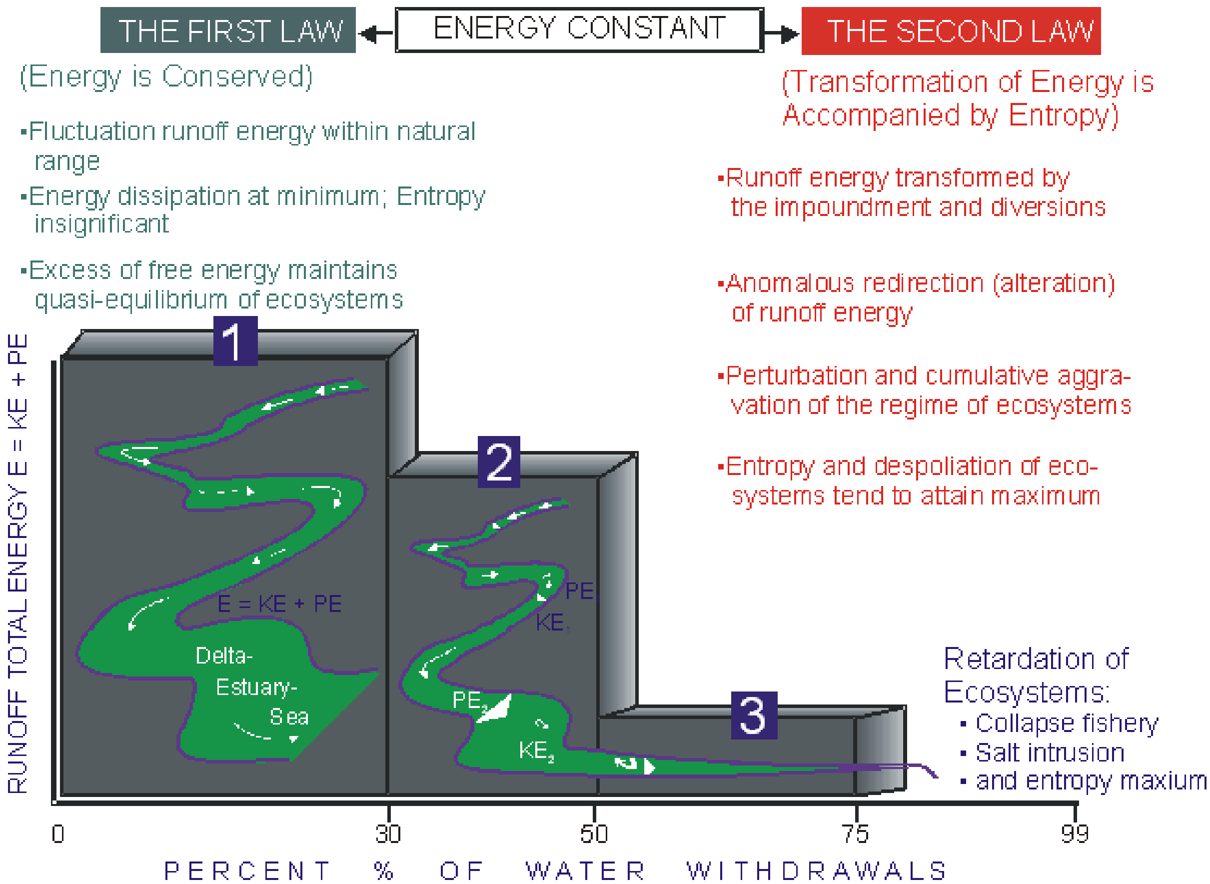

Figure 1. Application of Laws of Thermodynamics to River-Delta-Estuary-Sea Ecosystems

1- Normal, 2 - Subnormal, 3- Critical
KE- Kinetic Energy, PE- Potential Energy, ▷ Dams

However, when hundreds of major and numerous minor dams were built in 1950s – 1960s, then cumulative depletion of runoff to coastal seas became chronic features that inflicted mortal blows to some Mediterranean basins (Rozengurt, 1992; Zaitsev, 1998).

<u>The Black Sea and its northwestern region (NWBS).</u>

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The sea biota (about 180 - 200 species of fish out of 2000 marine organisms) used to inhabit about 4.2% of its volume (V = 547,015 km^3), which encompassed life-sustaining surface layer between 0 to 150 meter depths. The rest of the Sea was anoxic for all living creatures because two layers of density discontinuity significantly restricted vertical mixing between surface and stagnant deep waters. Since time immemorial, excess of runoff + rainfall over surface evaporation used to be the principal ecological feature of the Sea whose environmental essence has been given by Nature' certain limitations on runoff's withdrawals. In other words, seasonal and perennial norms of rivers' discharges and their deviations have determined the ecological significance of the sea's three regions (Bol'shakov, 1970): 1. Northwestern, 2. Northeastern, and 3. Southeastern. In the 1930s the Soviet fishery fleet was able to harvest in these regions which experienced the manifestation of natural runoffs about 200,000 tons valuable fish; in addition, nearly 2,000,000 dolphins were able to catch thousands of tons of fish for food. The NWBS (V_{volume} = 1150 km^3) was the most dynamic and productive part of the Sea. The NWBS accommodated in average about 264 km^3 out of a total unimpaired runoff of 392 km^3. Among three major rivers (Danube, Dniester, and Dnieper) emptying into the region, the Danube was and is the greatest source of freshwater (R_{avr} = 198±6 km^3; R_{max} = 296 km^3 (1941); R_{min} = 125 km^3 (1921); at the same period (1910 - 1960) the Dnieper and Dniester rivers discharged in average of 54 km^3 and 10 km^3 per year, respectively (the rest provided by some minor rivers). Thus, the NWBS accommodated about 75% total river runoffs to theBlack Sea. Spring flooding (late March – June) amounted to 55% - 60% of annual runoffs (Rozengurt, 1974).

This phenomenon controlled advection and entrainment of 1450 ±70 km^3 of the NWBS outflow to the open sea, saturated with many hundred tons of oxygen (up to 9 mg/liter). This well-mixed cooler and denser brackish water masses sank into the underlying marine, slightly saltier but warmer water of lower density. This was not only enough to satisfy the shelf's oxygen demands, but also to dissolve poisonous hydrogen sulfide at of 200m to 500 m slope depths. The combined annual discharges were able to entrain substantial volumes of coastal brackish water (1180 ±100 km^3 marine inflow to the NWBS). Annually, about 2630 km^3 of seawater (2.3 times the volume of NWBS) was in renewal over a period of 6 to 7 months, alleviating stagnation. It is important to emphasize that density, temperature, and wind - driven circulation commanded the oxygen enrichment of thousands of cubic kilometers of subsurface seawater masses.

Note the Sea of Azov outflow through the Kerch Strait had enormously enhanced the oxygen and organic elements concentration of the eastern Black Sea that affected very positively its fishery. Hence, the foundation of their coexistent continually maintained the food chain, i.e. of 60% of total biomass of the entire Sea, including a rich fish diverse, namely: 121 marine and 34 freshwater species. Moreover, the NWBS used to be teeming not only with fish but also about 7 to 9 million tons of raw mass of edible mussels and oysters. At the same time, almost 15,000 km^2 NWBS bottom was covered with about 10 million tons of the unique sea weed (Phyllophora) which provided a food and cover for up to 70% of the commercial landing of valuable fish before the dams became operational.

However, since 1950s the major spring runoffs draining to the NWBS have been subjected to gradual increasing diversions: Danube 28% to 40%; Dniester 45% to 75%; and Dnieper 45% to 85% of runoffs, and their reservoirs now accommodate 44+ km^3, 4+ km^3 and 35 + km^3 water, respectively. Annual and spring water withdrawals from the Dnieper and Dniester have reduced to 20 km^3 and 4 km^3 –5 km^3, respectively. In the last few decades, the remnants of spring deviations of impaired runoff from unimpaired volumes reach up to 45% - 85% (instead ± 25 ± 30% natural deviations for unimpaired runoffs). This implies that the current annual and especially spring regulated runoff correspond to dry or critical dry years of what otherwise would have been average runoff for the Dnieper and Dniester estuaries under pristine conditions. Note that natural chronic dry events of these kind are rare and particular stressful, they are usually typified by a very low probability of occurrence (1 to 3 times per 25 to 45 years of subnormal wetness).

For example, the Dniester spring (April through June) average outflow (1.5km^3) to the estuary reduced to75% of its spring norm, and annual regulated runoff (4.5 km^3) constitutes of about 45% of its norm (10.2 km^3). Moreover, the frequency of occurrence of dry, critical dry or drought-like conditions (particularly in spring) have increased up 3 to 6 fold in comparison with the same period under unimpaired conditions. Such persistent dewatering led to a gradual impoverishment fish in coastal sea ecosystems. This stagnation places the NWBS in grave peril (Rozengurt, 1991; Zaitsev, 1998). The truncated flooding cannot force vertical and horizontal mixing (entrainment) or turnover of marine waters much time as it was before water withdrawals. Note that between 1955 and 2002 the NWBS was deprived of about 2280 km^3 of freshwater, including 25% to 35% of Danube runoff (800 km^3 - 840 km^3), presumably diverted by the Central European countries. These cumulative losses exceed that of the NWBS volume, not counting the Sea of Azov spring runoff' losses.

Fresh water perennial deficit to the Dnieper and Dniester estuaries exceed 330 and 130 times their volumes, respectively, or nearly half the volume of the NWBS; runoff depletion triggered the measurable increase salinity intrusion into estuaries and deltas. Diversions make impossible for a current exhausted spring runoffs to provide mixing and life-giving substances, or to move down toward deep waters of the NWBS slope (200m - 300m). This hampered oxygen renewal and increased detention times, which, in turn, triggered the rise of hydrogen sulfide concentration even in the layers of 50 to 100 meters. The hypoxic water masses moved up to the lower boundaries of photic zones and caused mass mortality of shelf biota (over 15,000 km^2 bottom is now stagnant and anoxic). This triggered the disintegration of the Phyllophora, millions of tons benthos organisms and demersal fish. In practice, this development has menaced the entire Black Sea. It is conceded that under conditions of runoff deficit, the introduced agricultural nutrients to coastal water have been an overriding factor in eutrophication of the NWBS shelf. Chronic seasonal blooms may substantially degenerate even the remnants of marine habitats. Under such conditions virtually all attempts to slow down the degradation of lower rivers, estuaries, and coastal sea by pollution control or artificial fish-breeding hatcheries have failed to work. Furthermore, the summer releases of water from the dams accelerated development of discontinuity layer that appears to have isolated underlying water masses at depths of 8-40 meters. This resulted in nearly complete cessation of deoxygenating in 60% - 70% of the NWBS deep and bottom layers (since the late 1970s over 20,000 km^2 has been contaminated with hydrogen sulfide). In addition, detention time (known as Dynamic Index of renewal of the water body) increase from 11 to 150 days for Dniester and Dnieper estuaries, and from 180 to 360 days for the NWBS. Consequently, nutrients from agricultural fields have more time to be the major catalysts of catastrophic eutrophication over 29,000 km^2 of the NWBS surface (about 40%). The thick, fleshy mats of micro-algae in the summer has reached several kilograms per cubic meter and exceeded several thousand times of normal algae concentration. What used to be the granary of the entire basin is now seized by hypoxia.

. The niche formally ccupied by shellfish, red algae and fishes has been filled (1973-1987) by hundreds of million tons of jellyfish of the class Aurelia and Rhizostoma. But in 1989-1990, their abundance was suppressed by another jellyfish-like species (Gucu, 2002) Mnemiopsis leidyi (a ctenophore) reaching about 800 million tons that significantly depleted food resources for fish on the account for over 90% of total zooplankton biomass of the Black Sea. Scientists linked the catastrophic development of the ctenophore to the lack of natural predators (fish), which first appeared to be the victims of poor management of quantity and quality of inland water resources. It is important to point out that the invasion medusae lagged by water withdrawals10 to 15 years before interrupting the existing dynamic equilibrium. Finally, the Black Sea shifted toward a new equilibrium in which historical coexistence of major elements of the food chain and its consumers have been eliminated.

***The Decline of the Sea of Azov*.**

The Azov basin was once the richest sources of food resources whose volumes per square kilometer exceeded many times over other known productive seas and estuaries. According to some reports, the annual commercial catch in the 1930s reached 300,000 tons, including 136,000 to 167,000 tons of valuable fish: such as beluga, sturgeon, sevruga, herring, walleye, bream, and roach. Such yield was related to the unimpaired runoffs of the Don (in the north) andKuban (in the southeast) rivers (Brofman and Hlebnikov, 1985; Simonov, 1985). The Don and Kuban rivers runoff constitutes 95% of historical norm (R= 41- 43 km^3). The remaining 5% is confined to the irregular flow of numerous minor streams. The Sea of Azov (V=320 km^3) is an exceptional by shallow (maximum of 14 meters) transitional ecosystem typified by brackish water masses. Characteristics of water masses vary greatly in space and, attributed to substantial runoff variations, and rather essential, year-round salt and water exchange with the Black Sea through the Kerch strait. Naturally, the Crimean Peninsula partially divides the Black Sea into two highly productive estuarine areas: Northwestern and Northeastern. The latter includes the Sea of Azov and the vast adjacent shelf of the Black Sea.

In the Sea of Azov as in the NWBS before construction of dams started in the 1950s, the combined spring flooding, whose duration used to be equal to 30 to 45 days, provided for low salinity (10.6 ‰) of about 0.8 area of the Sea where anadromous and semi-anadromous fish could thrive. The flood carried out substantial amounts of nutrients and oxygen and maintained exceptional conditions for migration and spawning. The Sea of Azov fauna comprises 114 species of fish that include (similar to the Black and Caspian seas) members of freshwater and Atlantic-Mediterranean complexes. But only 16 out of 114 fish species inhabiting the sea are considered to be commercially valuable, including some semi-anadromous and anadromous forms. In the Sea of Azov the 1930s commercial fish catch was equaled 80 kg/hectare and or 6 to 25 times higher than the corresponding harvest in the Caspian and Black seas in the same period. However, the impoundment of rivers: Don (1952); Kuban (1948,1974) and Phedorovsky water diversion network (1967), modified the stochastic-periodic nature of runoffs to a deterministic, i.e. to the detriment of the marine environment.

The Tsimlyanskaya Dam eliminated 100% of spawning Don River' ground of the giant Russian sturgeon beluga, 80% for a lesser sturgeon, and 50% for herring and sevruga. The Krasnodarskaya Dam (Kuban River) blocked all spawning grounds of sevruga, shemaya, vimba, and other valuable fish. Consequently, the annual catch of valuable fish amounted to a fraction of the pre-project years. The vast network of artificial reservoirs and ponds of 5,500 km^2 catches 40 to 60% of historic spring flow and over 30 to 50% of an annual norm; therefore, the combined regulated runoff to the Sea varies between 20- 28 km^3 or less per year. These volumes constitute 49% to 68% of the deviations of the annual norm, for a regulated runoff up to –32% to -51%. This frequency of occurrence of subnormal and dry years exceeds by several times their natural probabilities had no impoundment taken place. As a result, cumulative spring losses reached around 750 km^3. This is more than 2.3 the volume of the Sea of Azov. Subsequently, such runoff depletion facilitated the Black Sea's intrusion into the Sea of Azov through the Kerch Strait. Correspondingly, salinity of the sea has increased from 9-9.5 g/L to 14 g/L and up to 16 g/L in the southern part of Sea after only 15 years. Note that this increase was exacerbated by exceptionally subnormal total runoff in 1967 – 1977, whose volume equaled 25 km^3 per year in average.

This runoff deprivation, coupled with increase volume of point and non-point discharges, led to the rise of chloride, magnesium, sulfate, and other unnatural chemical elements attributed to agricultural drainage and industrial discharges. This, in turn, triggered increases in the frequency of occurrence of hypoxia from 4 m depth to maximum 14m over 60% of the Sea. The lack of oxygen spelled out a mass mortality of fish and shellfish almost annually during the last two decades. The climax of this event has taken place in the late spring and summer-early autumn when the dense blooms of algae occur. Such seasonal outbreaks are unprecedented in their severity, frequency and spatial scope and put the sea environment in peril. The short-lived million tons of algae die and sink to the bottom, where upon decaying they consume the already depleted oxygen. As a result, the bottom water is contaminated by lethal hydrogen sulfide. Today, the insignificant Don and Cuban inflow cannot carry away point or non-point wastes or repel salt intrusion from the sea. In addition, it cannot provide the ranges of nutrients, and other dissolved constituents necessary for the sustaining of normal conditions of fresh or brackish water fish, eggs, larvae and fry. Consequently a precipitous decline of recruitment in stock and commercial fishery stocks occurred.

By the end of 1970s over 150 marine species from the Black Sea invaded the Sea of Azov. At first, the most aggressive among them were the two mussels: Mutilator and Mystiques move recently a massive die-offs of these mussels occurred. Finally, there has been an ominous foray of jellyfish (Aurelia and Rhizostoma) into the Sea of Azov and this invasion lagged nearly two decades after the beginning of the impoundment. It is sad, but ironic, that a former Soviet water policy management has brought the Sea of Azov to the edge of ecological and piscatorial disaster in less than 20 years, while Nature carefully experimented over 2 million years to create this richest of seas. Undoubtedly, for the Azov-Black basin water future is clearly bleak.

The Nile delta -coastal ecosystem.

The annual yield from two major sources of water - White and Blue Nile varied from 46 km^3 to 150 km^3 (Shanin, 1985; Rozengrt, 1992) and the average over periods at Aswan ranged from 84 km^3 (1900-1958) to 93 km^3 (1870-1920), at these periods, the annual and monthly runoff deviations at Aswan gauge were predominantly in the range of ± 25%. But only 35km^3 to 50 km^3 could reach the Delta-coastal Mediterranean, with the rest used by agriculture. Runoff used to provide in average 125 million tons of fine sediment, which were carried into the Delta and the eastern Mediterranean Sea. This load and its organic and inorganic substances have formed over millennia an enormously fertile arable land, wetlands, marshes, lagoons, beaches, and exclusive ecological conditions in the eastern Mediterranean ecosystem (200km in length of the Delta shoreline). The total landings of pelagic and demersal fish from the Nile estuarine-coastal area were equal to about 120,000 tons, while the prawn fishery yielded up to 12,000 tons. But now, after completion the Aswan High Dam, the Nile runoff is about 4 to 10 km^3 per year; its supports only fish yield in the range of 600 to 4,000 tones and several hundred tones of prawn. Delta water quality and supply at the edge of collapse.

The Aswan High Dam, as opposed to the six previously built dams, is the only structure capable of holding the Nile flood and providing over year storage was finally completed in 1964 and reached its operating volume 121.3 km^3 of stored water (or up to 95% of runoff in a drought). The extensive water withdrawals (up to 55 km^3) during June through September have completely eliminated annual and intra-annual runoff fluctuations. The rest was lost due to evapotranspiration (the evaporation from the Aswan reservoir is about 14 km^3 per year) and irrigation (about 85%). The impoundment of the Nile has reduced the historical annual norm of 35 km^3/year (1913 - 1963) in and out of the Delta to 5% to 17% of its norm. But even these remnants of flow have been heavily polluted by the returning agricultural discharges from a dense deltaic irrigation network.

Since 1965, the cumulative losses of evaporation have reached around 400 - 450 km^3 (nearly three times the volume of the dam, or 1.4 times of the Sea of Azov), plus about 1,000 km^3 of water withdrawn from runoff. These losses have a negative effect on the hydraulics processes of delta and the coastal zone. The following years, a gradual aggravation of the deltaic-coastal area has exceeded the known scale of long-term trends of natural processes (transgression and regression of sea level, climatic and sediment transport fluctuations) that molded and controlled the deltaic morphometric and morphological features in the course of its evolution over 35,000 years. The cessation of Nile runoff was accompanied by annual accumulation behind the dam of up 60 to 180 million tons of fine sand, silt and clay. For example, in 1964 – 1965, the Dam deprived its downstream delta and coastal perimeter of about 140-160 tons of fine sand, silt and clay. This jeopardized the capacity of the reservoir and, at the same time, evoked downstream scouring of the river bed because of intra-annual abnormal water releases from the hydropower plant and related modification of runoff velocity.

Over the last four decades the cumulative losses of runoff and silt spelled out the end of mighty and famous Nile plume, and facilitated erosion. The Delta 200 km seaside perimeter and the Nile deltaic perimeter have retreated toward the south of 125 to 175 meters per year (Halim, 1991). In reality, the inner Delta area has been transformed into a plumbing system superimposed by endless irrigation network, pumping stations, or barrages. The lack of runoff to flush out the salt from the delta, especially out of its northeastern part, partially isolated by the Suez Canal, has resulted in the transformation of this water body into a hypersaline lake and salt- pan. Moreover, the geomorphologic equilibrium between the delta and coastal zone has all but vanished. Besides, the Nile Delta-coastal ecosystem has lost a million tons of natural organic matter (silt and nutrients down to 10 to 20% of their perennial norms, respectively) that led to a ten-fold decline in the rich catch of the eastern Mediterranean sardines and prawns.

Something to think about.

Its appear a to be a common universality, namely if spring runoff diversions will cross limit of 25%- 30% of its perennial norm than a coastal ecosystems' dynamic equilibrium will be irrevocably distorted. All other perceived ills: pollution; over fishing; and, yes, even global warming, are secondary in importance to fundamental change brought by dewatering our global rivers. The ominous trends of the aggravation of hydrophysical and biochemical properties of coastal ecosystems have been exacerbated by (1) negligent recognition of the runoff limitations for diversions and their cumulative effects on coastal seas; (2) erroneous application of methods of a stochastic hydrology to combine database of unimpaired and impaired (deterministic) runoffs that make water development incompatible with living resources' survival, and (3) the lack of application of universal postulates of the First and Second Laws of Thermodynamics to evaluate the scales of ecological tolerance of ecosystems to excessive desiccation of watersheds by dams in concert with water withdrawals beyond which entropy of coastal seas tends to reach a measurable maximum. These events for the last decades gradually fortified eutrophication, oxygen deficiency (hypoxia or anoxia), and deprivation or even mass mortality of vegetation and living resources. The scale of such degradation and impoverishment of food chains poses not only threat to the sustainability of resources of coastal seas, but also to ocean fishery the world over whose decline of catches coincided with despoliation of Pacific and Atlantic coastal ecosystems (Fig. 2).

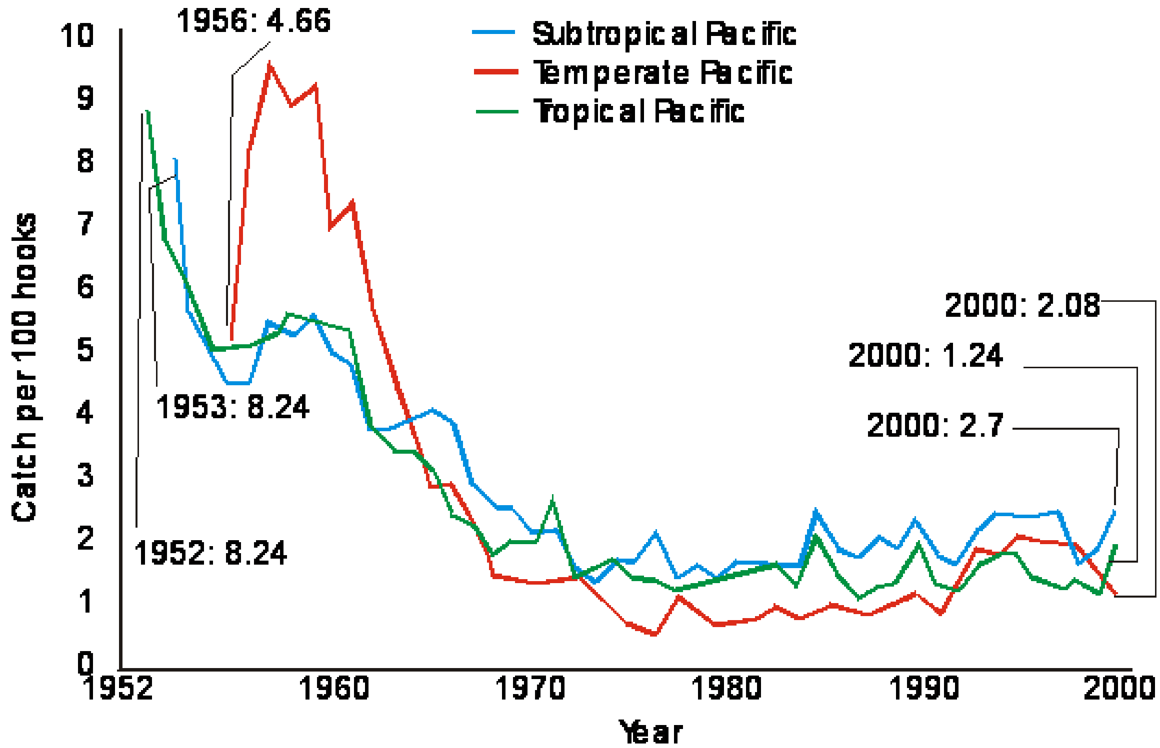
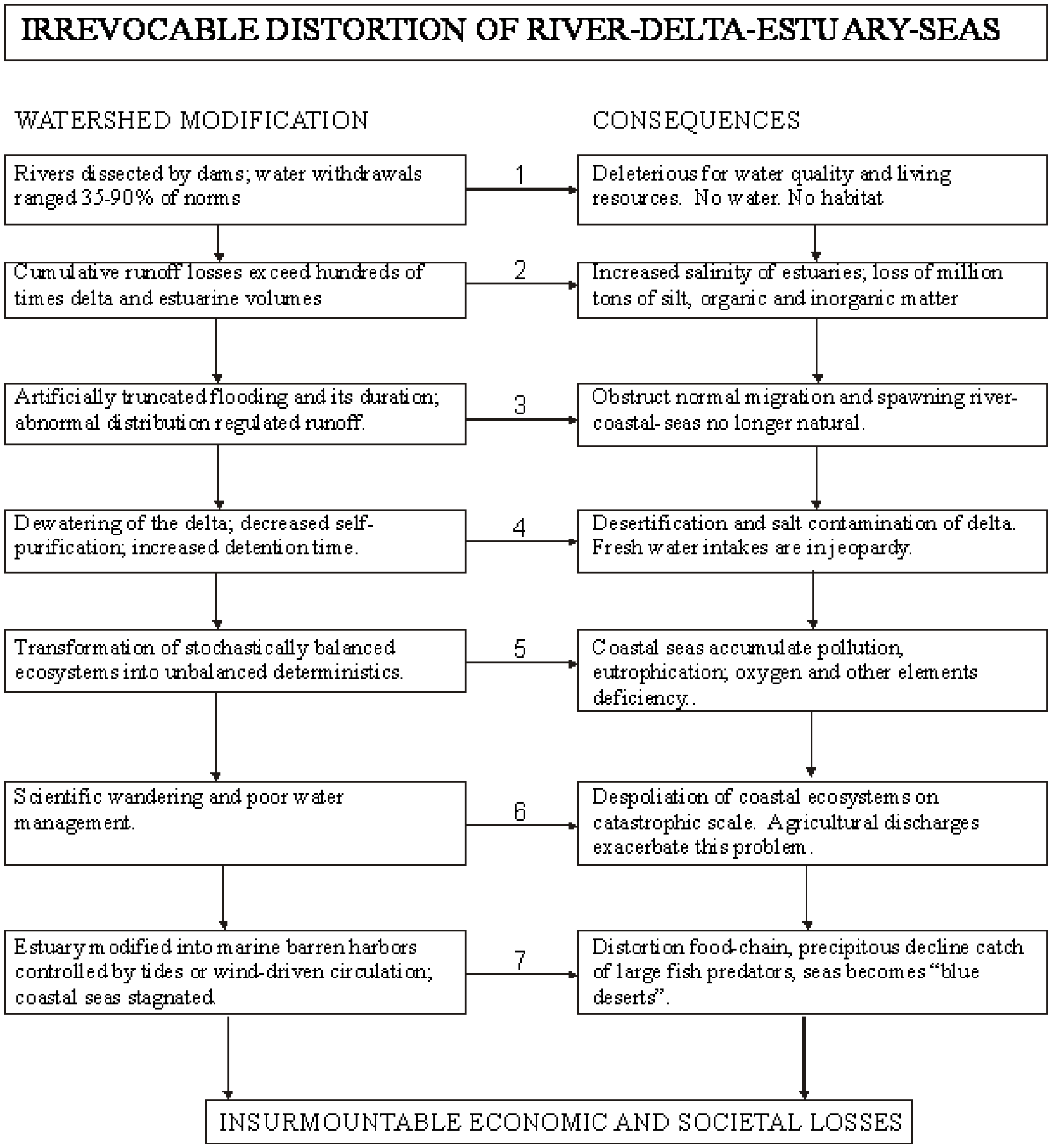


Figure 2. World wide large fish predator decline.
(Sources: Nature magazine; Ransom A. Myers and Boris Worm, Dalhousie University, Halifax, Nova Scotia; catch per 100 hooks, based on data from Japanese long-lining vessels)

Conclusion.

Coastal seas have experienced the effect of the “5**D**s” (**dams, diversions, dewatering, deforestation, and desertification**) with frightening similarity (Table 1) to the impoverishment of the northwestern Black Sea, Sea of Azov, Caspian Sea; Columbia River – coastal sea, the Delta- San Francisco Bay, Colorado River, Gulf of Mexico, Florida and the Nile River coastal ecosystems.

Table 1. Irrevocable distortion of coastal sea ecosystems



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