RUNNING ON EMPTY: THE DISTORTION OF COASTAL ECOSYSTEMS

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Abstract

Among numerous coastal embayments estuaries occupy special places whose immense influence on the adjacent marine environment and fisheries has been recognized by mankind since time immemorial. By definition, **estuaries are intermediate, dynamic, and cumulative links within the river-delta (estuary)-sea ecosystems where continual variable confluence, interaction, and mixing between river and sea takes place.** These processes result in development of four, specific zones of mixed water masses. In accord with the Venice International classification of 1958, they are typified by a strictly defined range of salinity, and other chemicals, and biological characteristics. As is known, the average salinity concentration of 5 g/L is a natural barrier for strictly estuarine species at early stages of their development within the avant-delta zone, the latter confined by 0.1 to 0.5 g/L salinity from the deltaic side.

These and other natural combinations of regime characteristics, developed under an umbrella of unimpaired runoff, have provided for the unique diversity and highest biological productivity of organisms directly or indirectly through food webs related to estuarine systems. But when the impoundment of watersheds has become fully operational, the river-coastal continuum has been mortally wounded, and fisheries have started to fade away since that time (Rozengurt, 1971, 74, et al., 1985).

For over the past two decades, the public perception has been that discharges treated wastewater into estuarine-marine environment was the major cause of their progressive impoverishment. Although some pollutants might have had measurable, progressive effects on the health and reproduction of living resources, the lack of sound scientific information on the more serious effect of the river impoundment on coastal systems has led many to mistakenly believe that more treatment or even "distilled" or "zero" discharges will restore the fishery. As a result, about $200- out of $541 billion were expended over the last two-three decades on pollution control to supposedly remedy the obvious depletion of fish and shellfish stocks. Despite this enormous cost and drastic improvement of treatment processes and the implementation of stringent water quality and fishery regulations (Clean Water and Magnuson Acts), the despoliation of coastal resources and economic losses has continued to persist.

It appears that the systemic depletion of river runoff over the same decades by numerous dams, water storage and the network of water conveyance facilities have had many times higher direct impacts on the aggravation of the regime and biota of the ecosystems in question than effluents (Rozengurt and Haydock 1981, 1993, 94). Ironically, in the Southern California Bight, the submerged ocean outfalls discharging at a distance of three to seven miles from the shore, at a depth of 60 meters are the closest to being a fresh water source, as over 150 rivers and streams of the Bight's watershed have ceased to exist due to impoundment. As a result of the latter, sport fishery has been rendered insignificant, kelp bed have declined, and over hundreds of miles of beaches have experienced inexorable erosion. This combined with other examples of ecological

deprivation of the Nation's coastal embayments (Columbia River Estuary, San Francisco Bay, Colorado River Estuary, Gulf of Mexico, Chesapeake Bay, etc.) provide strong support to the statement that river runoff was, is and will continue to be the ultimate, intrinsic guarantee of estuary-coastal systems survival. The pragmatic manifestation of this statement is based on the universality of the Laws of Thermodynamics, which govern the paths and control the runoff energy distribution and dissipation along the river course (Fig. 1). Note that the basic principles of river hydraulics and estuarine hydrodynamics are derivatives of the laws of conservation of mass and energy. The three major equations: (1) motion of water, (2) continuity of volumes of water exchanged between an estuary and sea, and (3) continuity of salt balance describe how these principles control the estuarine regime. Their solutions together with the results of a statistical analysis of stochastic, seasonal and perennial behavior of unimpaired runoff characteristics provides ample evidence that the lesser the runoff, the greater is the salt intrusion, and higher the salinization of an estuary (Fig. 2).

Simultaneously, the diminishing runoff adversely effects circulation, mixing and the entrainment phenomenon of runoff energy to repulse salt intrusion to maintain quasi-equilibrium dynamics of the estuarine ecosystems. The failure to recognize these and other universal regime features of coastal embayments by watershed development have contributed to: (1) alarming depletion of runoff to 60 to 90% of normal spring or annual values (note that the author had found that unimpaired intra-annual and perennial runoff fluctuations rarely exceed more then plus/minus 25 to 30% of their norms, Rozengurt 1971, 74, 85); (2) deprivation of the entire Central, South Atlantic and Western Pacific coastal zones from thousands of millions of acre-feet freshwater; (3) the current remnants of "regulated" flow, spring in particular, correspond to atypical chronic drought conditions regardless of wetness of the year (a seldom measured phenomenon for a unimpaired regime), their volumes no longer capable of absorbing even natural pollutants, or maintain adequate environment for migration and spawning, and (4) loss of millions of tons of oxygen, organic and inorganic matter and sediments so vital to coastal ecosystem survival. Concurrently, deltas and coastal erosion, subsidence of levees, oxygen deficit, hypoxia, eutrophication and agricultural discharges laden with chemicals have further aggravated the precipitous decline of habitat. The curtailment of 90% of migration routes and spawning grounds by thousands of dams together with the conversion of deltas into plumbing conduit have inflicted the final mortal blow to the Nation's and world fishery. Accordingly, an escalating entropy has become a new, highly negative property of a formerly healthy and rich coastal ecosystems. Subsequently, the new surrogates have only one thing in common with their natural, lustrous past - the same geographic locations and names on the maps. The reason why many prognostic contemporary models have provided erroneous results may be attributed to their inability to integrate the cumulative role of environmental losses (discussed earlier) on coastal systems. Thereby rendering their results nothing more than whistles in the dark. Arguably, the Nation's estuary is in peril.

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 (delta-estuary-coastal seas) despite the fact that their unnatural, broken river continuum has nothing in common with the history of their evolution should be considered as reductio ad absurdum.

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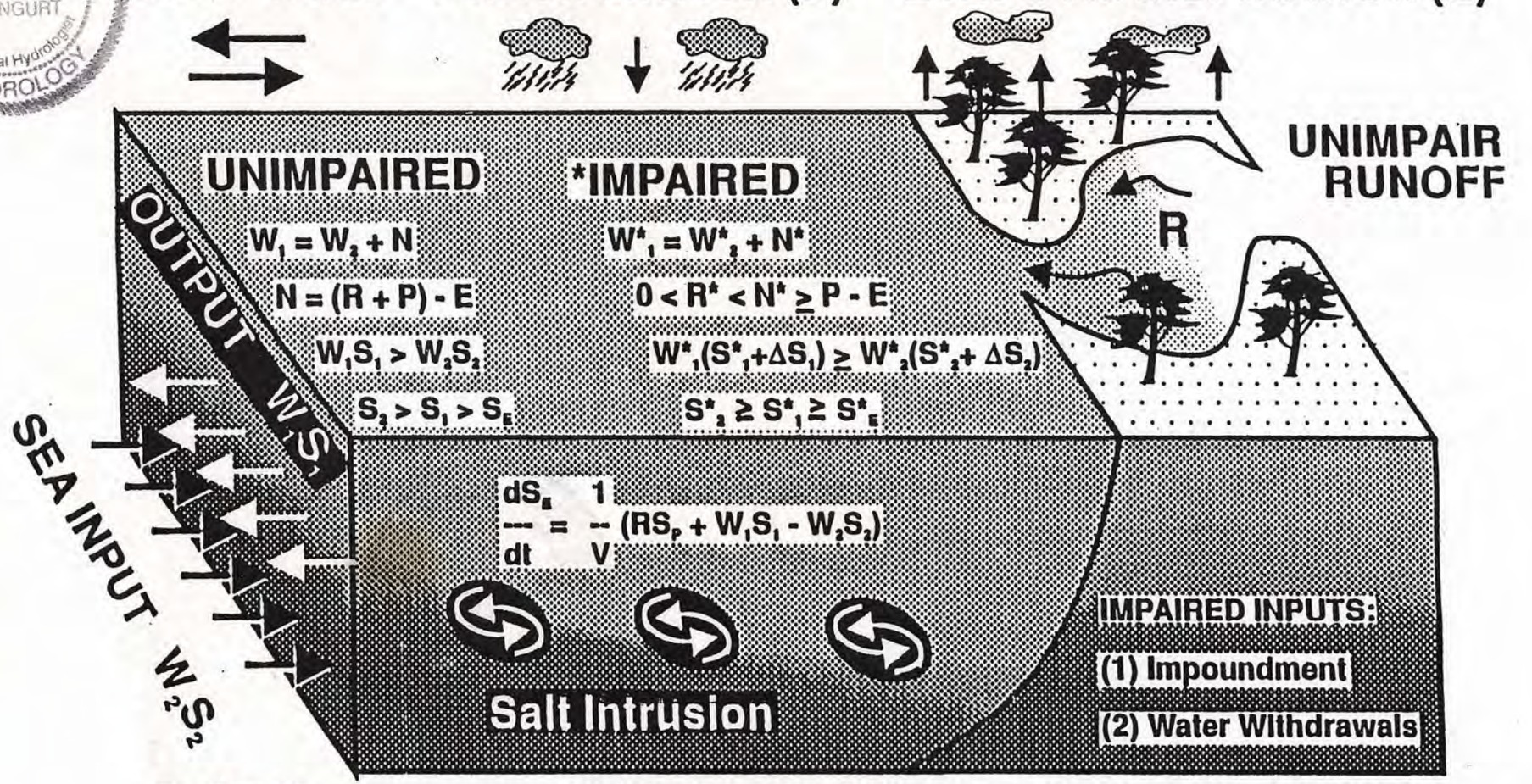
Conceptual Model of Estuarine Water and Salt Balance



R - Runoff

W_2, W^*_2 - Sea Inflow

W_1, W^*_1 - Estuarine Outflow

V - Estuarine Volume

N, N* - Fresh Water Balance

S_1, S^*_1, S_2, S^*_2 - Salinity Fluxes

S_E, S^*_E - Estuarine Weighted Average Salinities

Application of Laws of Thermodynamics to River-Delta-Estuary-Sea Ecosystems

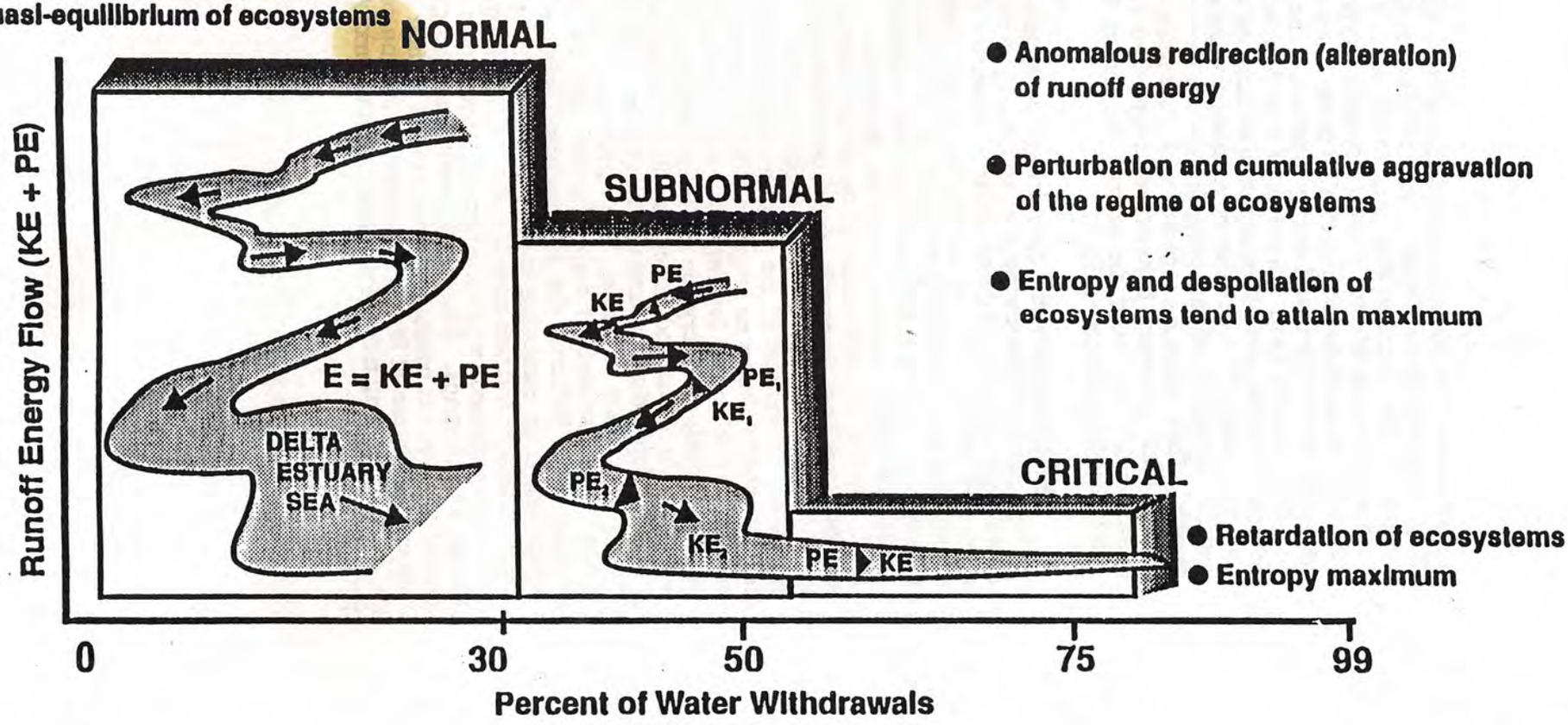
THE FIRST LAW ← **ENERGY CONSTANT** → **THE SECOND LAW**

(Energy Is Conserved)

- Fluctuation runoff energy within natural range
- Energy dissipation at minimum; Entropy insignificant
- Excess of free energy maintains quasi-equilibrium of ecosystems

(Transformation of Energy Is Accompanied by Entropy)

- Runoff energy transformed by the impoundment and diversions
- Anomalous redirection (alteration) of runoff energy
- Perturbation and cumulative aggravation of the regime of ecosystems
- Entropy and despoliation of ecosystems tend to attain maximum



- Retardation of ecosystems
- Entropy maximum