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Chapter 16

The Impact of Dams on Fisheries: Case of the Three Gorges Dam

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Rivers are the major channels for the passage of water, nutrients, organic material and particulate matter from land to sea. Yet humans have being continuously modifying river inputs into the ocean with their frequent unscrupulous use of land. In many areas, land is used for agriculture, forestry and mining, not to mention infrastructure and commercial development, and this has drastically increased the rate of terrestrial denudation (Fig. 16.1). Levels in excess of ten times the natural rate of erosion are not uncommon. The effect of increased denudation is, however, not necessarily reflected in an immediate increase in the flux, or flow, of particulate matter to the ocean. Rather, the eroded material from mountainous areas may be stored for centuries or even millennia in upland areas before it finds its way to the ocean. For example, there was rapid erosion in the hilly Piedmont areas of the central and southern Atlantic coast of the United States, starting in 1900. This continued until soil conservation methods were introduced during the first half of the 1900s. Even so, most of the eroded material still lies stored on the hill slopes and on the floors of valley streams-but not in the oceans.

16.1 The Effect of Dams on Deltas and Estuaries

One important point is that river basin development, notably from the construction of dams, has an immediate, profound impact on river inputs to the oceans. As far back as 2800 BC, the Egyptians built the Sadd el-Kafara Dam just south of Cairo (Newson 1997). Now the 35 000 dams worldwide trap sediments and regulate river flow which can result in a sharp increase in the amount of consumption of the river water. To illustrate this point, it has been well documented that the completion of the large Aswan Dam on the Nile River in Egypt, among others, has drastically reduced freshwater outflow and that this has been central to the substantial reductions in fish stocks in the connecting estuaries. Briefly put, dams block the down-stream transport of small particles, known as particulate matter, which replenish a delta and is an important source of nutrients and food for aquatic biota, or living plants and animals. Reduced sediment discharge contributes to the erosion of the delta, the transformation and disruption

Fig. 16.1.
Severe denudation upstream of the Three Gorges Dam (taken by the author in 1998)

of the entire ecosystem as well as to the starvation of fishes. The more subtle effects, however, go far beyond the deltas and the estuaries.

16.2 The Case of the Three Gorges Dam

Taking the case of the Three Gorges Dam (Fig. 16.2) as an example, evidence is provided to show that despite a large riverine input of nutrients to the East China Sea (ECS), only a small fraction (7% for phosphorus and 33% for nitrogen) of the total external nutrient supply that is required to support the new production of phytoplankton actually comes from that input. It is now clear that the major nutrient supply stems from the on-shore advection or transfer by horizontal currents of nutrient-rich, subsurface Kuroshio waters (Chen 1996; Chen and Wang 1999).

Since there is not so much nutrient outflow from the rivers, in the first place, any disruption of flow from the dam would not have a great effect on the not-so-important riverine nutrient flux to the ECS. It is argued, however, that the completion of the Three Gorges Dam on the Yangtze River is likely to result in diminished biological productivity in the ECS, home of the largest fishing grounds in the world. This is because the decreased water flow will reduce cross-shelf upwelling, or upward flow of subsurface water which is the major source of nutrients to the shelf. As a result, the disruption of water flow caused by the Yangtze River dam will indeed reduce the important flux of nutrients from upwelling.

Because of the ability of filaments and eddies to move water and other material on and off the continental shelf, investigations of buoyancy-forced flow must be conducted on spatial scales large enough to separate this effect (Henrichs et al. 2000). One method, using the so-called Box model, is frequently used for such an investigation (LOICZ 1997). For instance, cutting back the Yangtze River outflow by a mere 10% will reduce the cross-shelf water exchange by about 9% because of a reduced buoyancy effect, and, at the same time, it will cut the onshore nutrient supply by nearly the same amount. It can therefore be expected that primary production and fish catch in the ECS will decrease proportionately (Chen 2000).

16.3 Threat to Other Shelves

Similar situations probably exist in the case of other shelves with large freshwater inputs. For instance, the Gulf of Alaska and the shelves off Oregon are high in biological productivity but the rivers draining the Alaskan coast and the Columbia River have low nutrient concentrations and are probably not a significant source. Instead, upwelling is the most important driving force behind productivity (Henrichs et al. 2000).

From a global perspective, 60% of the largest 227 rivers are strongly fragmented by dams, diversions and canals. At least one large dam modifies 46% of the world's 106 primary watersheds (World Commission on Dams 2000). The number of large dams has increased sevenfold since 1950 and by the early part of the 1990s more than 13% of the global river flow to the sea had already been dammed or diverted. This figure may exceed 20% within a few decades (Nilsson and Berggren 2000; Revenga et al. 2000). In fact, Vorosmarty et al. (1997) estimated that more than 40% of global river discharge is already intercepted by the 663 of the world's largest reservoirs. The list of the major dams in Asia, as

Fig. 16.2.
Qutang Xia Gorge, one of the Three Gorges (taken by the author in 1992)

Table 16.1. Major Asian Dams (Source: United Nations, Guidebook to Water Resources, Use and Management in Asia and the Pacific 1995). Only dams with capacities of 10^9 m^3 or more are included

Name	Country	Year completed	Capacity (10^6 m^3)
Baishan	China	1984	4967
Dongjiang	China	1989	8120
Gezhouba	China	1992	1580
Liujiaxia	China	1968	5700
Longyangsia	China	1986	24700
Wuijiangdu	China	1981	2140
Yuccheng	China	1970	1220
Balimela	India	1977	3610
Bhakra	India	1963	9621
Hirakud	India	1957	8105
Idukki	India	1974	1996
Pung Beas	India	1974	8570
Ukai	India	1972	8511
Mangla	Pakistan	1967	7252
Tarbela	Pakistan	1976	13690
Thac Ba	Vietnam	1971	3600
Hoa Binh	Vietnam	1991	9450
Tri An	Vietnam	1985	1056

an example, is given in Table 16.1. Most affected will probably be wide shelves with large riverine inputs. Worldwide, approximately 40% of the fresh water and particulate matter entering the oceans is transported by the ten largest rivers, and this is in the form of a buoyant plume or feather-like formation on the open shelves. Globally, over 80% of modern carbon burial occurs on deltaic shelves which are associated with buoyant plumes (Berner 1982; Milliman 1992). These shelves face diminished fish production when damming reduces freshwater outflow and the buoyancy effect. Further, silicate retention in the reservoirs behind the dams affects the ecosystem structure, and certainly disturbs the biogeochemistry of the coastal seas (Ittekkot et al. 2000).

In isolated basins, such as the Black Sea, another threat cannot be overlooked. If all the major rivers leading to the Black Sea, namely the Danube, Dnieper, Don, Rioni and Sakarya, were completely dammed, for example, the decreased freshwater flux to the Black Sea could reduce the brackish or salty surface mixed layer, which could lead to a shoaling of deeper waters rich in highly toxic hydrogen sulphide. This would mean the deeper toxic waters would move into shallower zones. The consequence of this would undoubtedly have major environmental repercussions on the sea and on all of the bordering countries.

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