

**AQUACULTURE, FISHERIES, AND RECREATION  
IN THE PROTECTED AREA OF THE KRKA RIVER**  
**AKVAKULTURA, RIBARSTVO I REKREACIJA U ZAŠTIĆENOM  
PODRUČJU RIJEKE KRKE**

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Conference paper

Izlaganje sa stručnog skupa

*Summary*

*The experiences of fisheries, aquaculture, and recreation development in the protected area of the Krka River comprise a valuable case study with implications for managing other areas along Croatia's coast.*

*Keywords: Krka river, protected area, aquaculture, fishing*

*Sažetak*

*U ovom je radu opisano stanje i mogućnosti razvitka akvakulture, ribarstva i turizma na području rijeke Krke prije i nakon proglašenja nacionalnog parka. Također su opisane aktivnosti dopuštene na temelju Zakona o zaštiti prirode, u zaštićenom dijelu prirode - Nacionalnom Parku Krka.*

*Ključne riječi: rijeka Krka, zaštićeno područje, akvakultura, ribarenje*

**The Krka River**

**Rijeka Krka**

The Krka River, originating at the foot of Dinara Mountain, about 3,5 km northeast of the city of Knin, flows down a slope of 242 m over its 72.5-km path to the Eastern Adriatic Sea. For the first forty-nine kilometers, it contains freshwater; over the remainder of its passage—about 23.5 km—it is brackish. Hydrographic properties—and, accordingly, the resident flora and fauna—thus vary from those characteristic of full-strength seawater at the river's mouth to those of freshwater farther upstream (Buljan, 1969; Gržetić & Marguš, 1989). During most of the year—and depending principally upon the flow rate of freshwater—the water column at the river's mouth is strongly stratified (Gržetić et al., 1990). At other points along the lower river, some

degree of stratification also is typical throughout the year, with a summer thermocline and a winter halocline impeding exchange between surface and bottom layers. Intensive convection occurs in autumn, and especially in spring. The degree of vertical mixing during each season depends partly on water depth and prevalent meteorological conditions.

The surface lens of freshwater varies greatly and depends mainly on water level, precipitation, the state of the tides, and prevailing winds (Gržetić, 1990). Along the whole of the river mouth, changes in the quantity of freshwater affects salinity throughout the water column, especially at the interface between freshwater and sea water. Increased freshwater input is characterizes autumn and spring.

Hyper-saturation of dissolved oxygen is a particular feature of the river environment: During winter, oxygen in the surface layer may exceed 15 mg/l. At the same time, hypoxic conditions may occur near the bottom, occasionally at Skradin (Marguš, 1983; Petricioli et al., 1990). Hypoxic conditions have their origin in the decreased vertical exchange that results from a strong halocline and high freshwater flow rates. Thus, aerobic degradation of labile organic material in the bottom layer proceeds at a rate that is greater than that at which oxygen is replenished from the surface layer. This lowers ambient dissolved oxygen (Gržetić and Marguš, 1989).

The lower section of the river mouth—from the Skradinski Buk waterfall and Prukljansko Jezero, to Fort St. Nikola and the entrance to the St. Antonio sea channel—experiences wide oscillations in the abundance of phytoplankton and zooplankton (Viličić et al., 1990; Mušin, 1990). This is caused by the high input of nutrients from the Krka River, as well as by significant variability in other ecological parameters.

Owing partly to high rates of primary production, the river mouth is home to a rich community of shellfish representing some fifty-six genera (Marguš,

\*Public Authority "National Park KRKA", Šibenik, Croatia

1998). The most abundant species are the Black Mussel (*Mytilus galloprovincialis*) and the European Flat Oyster (*Ostrea edulis*). Two protected species also are prominent: the Date Mussel (*Litophaga litophaga*) and the Pen Shell (*Pinna nobilis*).

In upper part of the river mouth, the Common Cockle (*Cerastoderma glaucum*) is the most abundant shellfish species. This soft-bottom bivalve, the distribution of which extends almost to the Skradinski Buk, may be found at densities of up to 1000/m<sup>3</sup>. In lower areas of the mouth, shellfish of the Veneridae family—the Warty Venus shell (*Venus verucosa*) and Calico Clam (*Tapes decussates*)—are the most abundant.

From an aesthetic point of view, their attractive colors, interesting shapes, and especially their characteristically comical jerky swimming motion make shellfish of the Family *Pectinidae* perhaps the most interesting—and certainly the most entertaining—members of the resident shellfish assemblage. Of six genera, the most colorful are the Variegated Scallop (*Chlamys varia*) and the Queen Scallop (*Aequipecten opercularis*); the prize for the most interesting shape goes to *Chlamys pesfelis* and the Pilgrim's Scallop (*Pecten jacobus*).

Regarding fish, large schools of *Lizza ramada*, and smaller schools of *Chelon labrosus*, frequently are present in the river mouth. The commercially important seabass (*Dicentrarchus labrax*) and seabream (*Sparus auratus*) favor the mouth's hard bottoms. Also found in the same area are *Dentex dentex*, Striped Bream (*Litognathus mormyrus*), Pandora (*Pagellus erythrinus*), and the Conger Eel (*Conger conger*). One species found in this area, but which is relatively rare elsewhere, is *Dentex gibbosus*.

Muddy bottoms have abundant populations of the European Eel (*Anguilla anguilla*), the John Dory (*Zeus faber*), and sundry other species of the *Gobiidae* Family.

## Aquaculture in mouth of river Krka

### Akvakultura u ušću rijeke Krke

The first attempts at aquaculture in the mouth of Krka began in 1979 when Californian trout (*Salmo gairdneri*) were introduced as an experimental species (Teskeredžić, 1982). After evaluation of the results of these trials, cage culture of *Oncorhynchus kisutch* (1981-1986) and *Oncorhynchus rodurus* (1985-1986) was introduced in commercial projects (Teskeredžić, 1981, 1983; Teskeredžić & Edwards, 1986, 1987; Teskeredžić & Teskeredžić, 1990; Teskeredžić et al., 1989, 1989a).

Long-term research on cultivation salmonids in brackish water, supported by the Institute Rudjer Boskovic (IRB), based in Zagreb, resulted in four commercial fish farms being established in the area: ACI-Briuni in Skradin (1984), two small family farms near Skradin (1985), and RO "Šibenka", located in the bight of Šarina Draga, near Zaton.

In 1988, total production was 85 MT/yr, comprising 42 MT of *Salmo gairdneri*, 40 MT of *Oncorhynchus kisutch*, 3 MT of *Dicentrarchus labrax*, and a small quantity of *Sparus aurata*.

The vicinity of the river mouth, owing to its naturally high productivity, traditionally has attracted both commercial and recreational fishermen. The commercial importance of the area's shellfish populations—the Black Mussel has been harvested in quantities of more than 100 MT/yr since 1979—has spurred several avenues of applied research. For example, investigations conducted from 1979 to 1985 were directed toward determining how the local oysters and mussels best could be cultivated under prevailing environmental conditions (Teskeredžić, 1979; Marguš 1983, 1985, 1987, 1991a; Marguš & Teskeredžić, 1983, 1984, 1986; Marguš et al., 1988, 1990, 1990a). Additional research centered on other shellfish with commercial potential. This latter group included the Noah's Arc Shell (*Arca noae*), the Variegated Scallop (*Chlamys varia*), the Queen Scallop (*Chlamys opercularis*), the scallop *Flexopecten flexuosus*, and the Pilgrim's Scallop (*Pecten jacobus*) (Maruš, 1990, 1991, 1991b, 1994; Marguš et al., 1990b, 1992, 1993, 1993a).

These efforts resulted in defining procedures for the cultivation of mussels and oysters (1983), as well as those for *Pecten jacobus* and *Chlamys varia* (1989). In 1990, four more farms, with a combined production capacity of about 150 MT/yr, were established in the area. However, owing to the war, changes in regulations, and lack of financial support, the area's fish farms were closed; and the shellfish farms only just managed to survive.

Currently, the RO "Šibenka" fish farm, near Zaton, has stopped production, though its cages yet remain at their original moorings. The salmonid farms in Skradin, which stopped operations during war, were unable to revive production because they now find themselves located within the protected area of a national park. Operations were moved to new location, and renewed production yields about 20 MT/yr.

The shellfish farms expelled from the national park now are distributed over 25 localities and produce about 500 MT of mussels, and about 10,000 pieces of oysters, annually.

Despite the positive results derived from the aforementioned research into their commercial cultivation, the supply of *Pecten jacobus* and *Chlamys varia* still is limited to labor-intensive harvesting from the area's rich natural shellfish beds.

## Aquaculture after establishment of the Krka National Park

### Akvakultura u ušću rijeke Krke nakon proglašenja NP "Krka"

At the time of the first aquaculture trials in Skradin, the area from the Skradinski Buk waterfall

to the bridge of Šibenik already was under official protection—since 1967, in fact—as a nature reserve. A subsequent law established the Krka National Park. This extended protection to areas in which fish and shellfish farms already were in operation.

In 1989, the National Park's Physical Plan for the period through 2015 was adopted. It explicitly takes into account existing and proposed mariculture installations. Of importance in the present discussion, the Plan states that, after reviewing appropriate scientific studies, mariculture within the jurisdiction of the Krka National Park will be permitted only in designated areas. These areas, as defined in the Plan, are by the Raslina settlement, at the coast, and in the basins and in the floating basins in Krka River between Prokljansko Lake and the Bay of Zaton. Specific sites will be identified according to the results of more detailed study, referred to in the Plan as the Dissertation.

This Dissertation should have been completed in three phases, from 1988 through 1993, by the IRB. However, only the first phase—dealing with the Prokljan area—was finished. Work on the next two phases, meant to project the direction of future development, was interrupted by the war. To date, these studies have not been completed.

Especially during the early 1990s, the Park was being subjected to illegal fishing activities, which even included the particularly destructive use of dynamite. The need to control aquaculture and other activities in the Park was obvious. Thus, in 1993 the Park's management joined with the IRB to devise a plan to undertake applied aquaculture research and to implement a comprehensive monitoring program. The goal was to pursue a course of action that would contribute to protecting the area in a more efficient way. (It may be noted that this action was taken despite admonitions from the IUCN regarding what they considered to be the inherent incompatibility of commercial aquaculture within the realm of any national park.)

Demonstrating visible support for aquaculture within the Park also was intended to raise the consciousness of the local people to the potential economic value of the natural resources in their region. The message was this: If properly managed, the Park had the potential to provide a sustainable source of income for the local economy, both from tourism *and* from aquaculture. It was hoped that by instilling this attitude in the surrounding communities, illegal fishermen might be transformed into legal farmers; environmental outlaws might become responsible stewards of the natural resources on which they and their families depended for their livelihood.

Pursuant to this agreement, in 1994 tenders were invited by the Ministry of Environmental Protection and Physical Planning (MEPPP) for mariculture projects within the Park. However, because fish farming relies upon broadcasting high amounts of formulated feed, some fraction of which enters into the natural ecosystem, preference was given to

shellfish farming. MEPPP subsequently granted eight contracts for temporary use of water plots within the confines of the park for the purpose of cultivating shellfish. At the time, each of these sites already was under cultivation.

IRB proposed that money collected from the annual license fees initially be used to finance a research project entitled: "Aquaculture as a means for protecting and improving the lower reaches of the Krka River". After finishing this project, it was intended that future annual fees be dedicated to support of a program to monitor the quality of both water and sediment, especially in the vicinity of the licensed farms. This project, however, never was completed. At the end of the war, priority was given instead to building the new Adriatic highway, as well as to a number of other public-works activities.

Legislation proposing amendments to the law on the Krka National Park was brought to the floor of the Croatian Sabor (Parliament) in 1997. According to that law, the area of the flooded river mouth, from Skradin bridge to Šibenik bridge, was excluded from the National Park. From that moment on, the government of Šibenik County regained jurisdiction over aquaculture in that area. Thus, decisions on concessions in the area of the flooded mouth of the Krka River rested with the Šibenik County Assembly.

At the time at which contracts with developers were being concluded, no Physical Plan yet had been completed. Concessions thus had been granted for a period of only four-years. Each concession holder had to agree to stop his activities, in the case that the Physical Plan raised objections, *a posteriori*, to operations at their particular site.

The yet-to-be-published Physical Plan of Šibenik County and the town of Šibenik will propose sites for fish and shellfish development in the Krka's flooded mouth. Recommendations will have to navigate a defined legal procedure before being implemented. After their publication, the Assembly will be able to grant concessions for twelve-years, a much more reasonable term for serious culturists.

## Recreational fishing in the Krka National Park

### *Rekreacijski ribolov u NP "Krka"*

The Law on Nature Protection regulates basic principles pertaining to the operation of National Parks. For example, the law forbids activities that threaten the natural order of the ecosystem, as well as any unauthorized economical use of natural resources.

Article IV of the Law prescribes behavior and limits of activities that may change and/or damage protected areas. Stated another way: Only activities that do not damage and/or change the original characteristics of protected areas are permitted.

Based on this Law and relevant amendments referring to the Krka National Park, aquaculture is

not permitted within the boundaries of the Park. In fact, the only activity that is allowed is sport fishing, and this under conditions prescribed by the Book of Regulations. The Book permits fishing from the shore of the Krka and the Čikola at sites specified by the Park Management. Of the various methods of sport fishing that may be practiced, only classical angling—and that with only one artificial fly as bait—is allowed. Additionally, a one- to seven-day permit is mandatory. (The permit's cost depends upon its duration.)

Further, recreational fishing is not permitted during the closed season; and only one kg of fish per day per permit is allowed. Size limits also are to be enforced. For example, trout less than 30 cm in length must be put back into the water.

With the exception of scientific and educational activities—waivers for which must be granted, on an *ad hoc* basis, by MEPPP—fishing, hunting, and collecting of bivalves and all other aquatic organisms is forbidden within the Krka National Park.

The situation may be expected to continue to evolve. At the present, however, despite the conflicts encountered—and resolved—in the recent past, the current arrangement addresses the interests of both conservationists and aspiring commercial mariculturists: A significant part of the Krka's natural resources is under protection; and economic development is proceeding at a reasonable pace.

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