Ribarstvo, 68, 2010, (2), 79—92
N. Ajanović et al.: Fish Hatchery in the Municipality of Bosanska Krupa

ISSN 1330–061X
CODEN RIBAEG

UDK:639.3.04(497.6 Bosanska Krupa)
Professional paper

FISH HATCHERY IN THE MUNICIPALITY OF BOSANSKA KRUPA IN NORTHWESTERN BOSNIA AND HERZEGOVINA: A SUSTAINABLE DEVELOPMENT PILOT PROJECT

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Summary

The Norwegian Government financed the project GCP/BIH/003/NOR "Support to Income Generation through establishment of a Fish Hatchery in Bosnia and Herzegovina", worth one million US dollars, that includes the construction of a fish hatchery on the banks of the River Krusnica in order to create jobs and incomes for people living with disability in Bosanska Krupa. The hatchery is dedicated to producing local strains of brown trout (*Salmo trutta* m. *fario*), grayling (*Thymallus thymallus*) and Danube salmon (*Hucho hucho*) for re–stocking the natural waters of the Krusnica/Una River catchments (and larger Bosnia and Herzegovina and Danube basin), support the rehabilitation of fish populations and to help revitalize local tourism. The Regional Office for Europe and Central Asia (REU) of the Food and Agricultural Organization of the United Nations (FAO), based in Budapest, Hungary implements the project in close collaboration with the Sport Fishermen's Association of Krusnica, which currently has 351 members. A fish hatchery, a pilot Recirculation Aquaculture System (RAS) in the valley of the River Krusnica, is the first of its kind in Bosnia and Herzegovina. It is suitable for production of 250,000 to 450,000 fingerlings annually. Five war invalids are employed at the hatchery continuously since fish production began in November of 2008. The production technology learned by the staff abroad was adapted to the local conditions. The hatchery is expected to be self–sustainable in its operation from sale of fingerlings. Since the hatchery activity has received wider publicity, anglers' interest in the River Krusnica and River Una has increased. Further increase

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in the number of visitors is expected after restocking the fish into the river, since the bigger fish populations will attract more and more anglers.

Key words: Fish Hatchery, RAS, Rivers Krusnica and Una, Sustainable Development, Brown trout, Grayling, Danube Salmon, Fly fishing, Disabled

INTRODUCTION

In northwestern Bosnia and Herzegovina, there was widespread overharvesting of fisheries resources before war broke out in 1992. Close to four years of war in the country put even greater pressure on fisheries, mainly due to people's lack of food and general lawlessness. In the post–war period, the practice of overharvesting continued, resulting in an extraordinary decline in fish populations (Ajanovic, 1999; FAO, 2003). This sustainable development project proposes that a fish hatchery be developed as a pilot project for the Municipality on the River Krusnica (FAO, 2003). It is important to understand that development of a fish hatchery on its own will not solve the problem of the fisheries' situation in the waterways of the Municipality of Bosanska Krupa. The aquaculture facility is only one part of the overall remedy for fisheries in the municipality, the Canton and the country. The initial role of the hatchery focuses on rehabilitation of fish stocks in the municipal waterways. As the number of fish increases, the hatchery should shift its production focus to the marketplace (i.e. selling the fry to other municipalities for stocking and to other fish hatcheries to be grown for human consumption). Operation of the aquaculture facility needs to be in accordance with improvements in a fisheries management plan that includes habitat maintenance, fish conservation, fish–use allocation, education, enforcement, inventory, monitoring and research and improvements in sport fishing regulations (Ajanovic, 1999). Only then can we expect to see improvements in fisheries resources of the Municipality of Bosanska Krupa, the Una–Sana Canton and Bosnia and Herzegovina (Ajanovic, 1999; FAO, 2003).

THE PROJECT

The Norwegian Government financed the project GCP/BIH/003/NOR "Support to Income Generation through establishment of a Fish Hatchery in Bosnia and Herzegovina" that includes the construction of a fish hatchery on the River Krusnica in order to create jobs and incomes for people living with disability in Bosanska Krupa. The hatchery is dedicated to producing local strains of brown trout (*Salmo trutta* m. *fario*), grayling (*Thymallus thymallus*) and Danube salmon (*Hucho hucho)* for re–stocking the natural waters of the Krusnica/Una River catchments (and larger Bosnia and Herzegovina) in order to support the rehabilitation of fish populations and to help revitalize local

tourism (FAO, 2003). The Regional Office for Europe and Central Asia (REU) of the Food and Agricultural Organization of the United Nations (FAO), based in Budapest, Hungary implements the project in close collaboration with the Sport Fishermen's Association of Krusnica, which is a local NGO with currently 351 members.

The project idea originated from a Master's Thesis (Ajanovic, 1999), developed between 1997 and 1999 at the University of Calgary and was later endorsed by government officials, resource managers, scientists, and local Sport Fishermen's Associations that were familiar with the area of the Bosanska Krupa Municipality, the Una River system, and the status of native salmonids (FAO, 2003). FAO, in association with the above groups and local governments, was involved in formulating the full–fledged rehabilitation and development project. The project became operational in December 2003 with the generous contribution from the Norwegian Government in the amount of US$1 million.

FAO has a longstanding and recognized capacity in technical advice for aquaculture, particularly in hatchery management and restocking exercises. FAO also has expertise in balancing conservation and use of natural resources, promotes responsible inland fisheries and aquaculture and increases their contribution to food security. FAO through the project outlined normative guidelines on broodstock management, genetic resource management and problems related to introduction of alien species (F A O, 2003). These concepts are put into practical use in the field in order to increase food security and enhance aquatic biodiversity.

The project indirectly contributes to the goals of multiple government programmes, first, for the integration of war invalids, and second, to environmental programmes. Although it is not directly linked to either of these programmes, its contributions are still important, especially when considering the limited resources the government has at its disposal.

The main outputs of the project are 1) the implementation of a fish hatchery on the Krusnica River, 2) trained hatchery staff, 3) the fingerlings of native fishes produced by the hatchery, and 4) income generated from the sale of fingerlings. The main outcomes are 1) increased fish in the Krusnica River, and 2) increased income of the local population from working at the hatchery and sales of fingerlings, and subsequently the improved nutrition because of human consumption of fish (Ajanovic, 1999; FAO, 2003).

The primary beneficiaries are disabled and fishers, directly employed at the project fish hatchery. Other fishers will directly benefit from the profits of the fish hatchery, which will be given to the local Sport Fishermen's Organization for uses advantageous to its members that include war invalids and other disabled people. Other interest groups will benefit in the long–term from overall economic development of the area and increased availability of fish. The project is being implemented by a non–profit company, Eko Riba Krusnica, which is owned by the Sport Fishermen's Association of Krusnica,

and will continue to operate the project fish hatchery after donors' (i.e Norwegian and FAO) assistance ends (FAO, 2003). The fish hatchery is designed to become financially self–sustaining by March 2010, with the first sales of young fish. The project has provided training in business management, marketing and the technology of fish production to company staff to render them fully competent to run the operation by the end of the project period. The sales of fingerlings to stock local fisheries should generate sufficient funds to support the hatchery (FAO, 2003). The project has increased the capacity of the local Sport Fishermen's Association to produce fish and manage the fishery in a sustainable and responsible manner. The hatchery produces only native fish with appropriate genetic characters to ensure environmental sustainability. Access to fishing rights will be controlled by the Sport Fishermen's Association of Krusnica to ensure social and economic sustainability.

The project brings together a variety of institutions concerned with environment, disabled people, sport fishermen, fish production, fishery management, and sales (Ajanovic, 1999). Partnerships include, among others: the Institute of Ichthyology (University of Sarajevo), Norfish and other commercial fish farms (that also trained project staff in large–scale production of salmonid fishes), Aelvdalen Institute in Sweden (that provided training to project staff in modern methods for production of grayling), AKVA Group Denmark (a leading development company of Recirculation Aquaculture System (RAS) technology, that designed the hatchery in Bosanska Krupa), the Organization of War Invalids in Bosanska Krupa and the Sport Fishermen's Organization of Krusnica.

The project had three phases. (i) In the first phase, between 2003 and 2005, the legal frames of the hatchery establishment and the technical/technological planning were completed with participation of national and international consultants as well as local experts. The road to the remote site of the hatchery, the building of the fish hatchery and a water supply pipe (constructed not according to the project's technical specifications and remains unused) from the source of Krusnica River were constructed during this phase. The pre–selected local staff of the project, war invalids, with disability ratings of 30% to 100%, were trained in Sweden, Finland and Bosnia and Herzegovina on fish production. (ii) Since February 2008, considerable activities have been carried out in order to complete the fish hatchery. According to the new global standards for the reduction of water use and for decreasing the environmental load of aquaculture activities, the fish hatchery is now based on water recycling technology, adapted to the site by AKVA Group Denmark, a company leading in development of this technology. (iii) The fish hatchery operation began in late 2008. The incubation unit of the fish hatchery was ready in this period in its final form, but the broodfish tanks and the nursery unit were still working as flow–through systems. However, a sufficient quantity of fish was produced in these temporary systems for stocking the water recirculation–based fingerling production unit, which is now complete. These

fish will be reared until the early spring of 2010 in the new system and will be used locally or sold for re–stocking purposes to other angling associations.

IMPACTS

Jobs were created for a few war invalids interested in carrying out active lives and utilizing their abilities to improve both their livelihoods and their environment. The hatchery itself contributes to rehabilitation of fish fauna by production of indigenous strains (brown trout, grayling and Danube salmon) of the target species and enhances sport fishing by increasing fish yields. Moreover, foreign experts have introduced new salmon breeding methods to support project work; these methods have been disseminated by the project. The distributed information will certainly positively affect the professional approach of regional farm managers towards fish genetics, therefore helping to maintain sufficient biodiversity in Bosnian waters.

MATERIALS AND METHODS

Pilot Recirculation Aquaculture System (RAS) in the Valley of Krusnica: First of its Kind in Bosnia and Herzegovina

As with all living organisms, fish affect their environment by consuming food and discharging metabolites. The consumption, the quantity of released materials and the chain of organisms that benefit from fish metabolites are well balanced in natural ecosystems. Stationary populations of living organisms, including fish, can develop and be maintained in these natural water systems. The ecosystem supplies the fish population with natural food and purifies the environment of discharged materials (Nielsen, 1994). However, this balance is disrupted if the fish population is artificially increased and its feed is supplied from outside the system (DANAQ Consult, 2001a, b; Bollerup, 2009; Bregnballe, 2010).

Whether this happens in a natural water body or an artificial rearing tank, the quantity of the discharged materials into the natural system (assuming a flow–through system in the latter case) increases and cannot be processed back into equilibrium by the ecosystem. With production of each ton of fish, about 300 kilograms of manure–quality material is also produced, out of it only about 20 kg N is converted by bacteria to gas form and gets to the atmosphere (Bregnballe, 2010). The consequence is the modification of the natural environment. It can be moderate, hardly appreciable in the short–term, but the process is also capable of rapid damage to the system and deterioration of water quality. This phenomenon has occurred in many countries where intensive farming of salmonids or other fish species has become widespread.

Fig. 1. Hatchery workers obtain brown trout for breeding using electrofishing
Slika 1. Ulov matica potočne pastrve uporabom elektroagregata

To avoid the above–mentioned consequences without decreasing fish production, in countries with high environmental consciousness, water–saving or water–reuse fish production technologies are used, including the application of Recirculation Aquaculture Systems (RASs). Of course, the quantity of discharged metabolites after consumption of a unit of feed is no less in the RASs than in flow–through or pond systems; however, RASs use mechanical and biological filtration to concentrate, degrade, and remove almost all of the waste materials from the fish rearing tanks, so they do not get into natural waters. The soluble wastes and feed are degraded in the biofilter by microbes, which use oxygen while releasing other gases to the air. Extra air or pure oxygen can also be added to the water to accelerate these processes (Bollerup, 2009; Bregnballe, 2010).

The Federation Law of Environmental Protection, recently introduced in Bosnia and Herzegovina, forces fish producers to take into account the environmental effect of these applied technologies. FAO suggested establishing the water–saving RAS system in the Valley of Krusnica, in accordance to its general endeavor for protection of the environment without decreas-

ing the production capacities. This RAS can serve as a pilot system for the region: it demonstrates an environmentally friendly alternative for fish production.

The Krusnica fish hatchery was established for production of brown trout, grayling and Danube salmon fingerlings for restocking purposes. Since the main target of the hatchery is to produce local strains of the target species, the broodfish are caught from the rivers near the hatchery before breeding. Electrofishing is used to obtain the broodstock (Fig. 1). This technique takes advantage a fish's attraction to a positively–charged electrode emitting a DC current in the water (Geertz — Hansen and Rasmussen, 2002).

The body tension the current induces on the fish draws them to the electrode, where they can be collected (Geertz — Hansen and Rasmussen, 2002; Ministry of Food, Agriculture and Fisheries, 1994). The effect is more pronounced in large fish, so the method is ideal for collection broodstock. Obtaining fish from natural waters in the vicinity of the hatchery helps to avoid the genetic degradation of the fish population, which would occur if the same closed group of fish were bred year after year (Ajanovic, 1999).

The hatchery was installed in a building of 620 square meters. It comprises of three production units in addition to service rooms (Fig. 2). Two phases of the production; i.e., the incubation and fingerling production, are carried out in RASs.

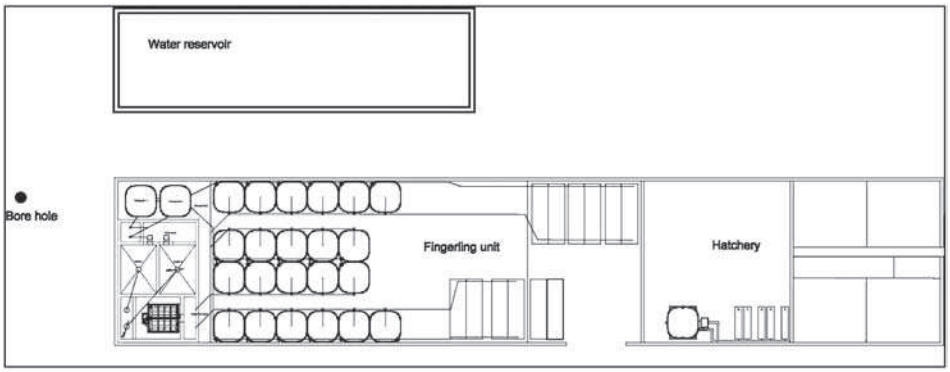

Fig. 2. This figure depicts the layout of the hatchery
Slika 2. Plan mrjestilišta

The broodfish are currently kept in flow–through tanks before breeding; however, in the future these tanks will operate as water reuse units. The hatchery was planned by the AKVA Group, a leading Danish company in RAS construction.

Fig. 3. Trout eggs are kept in hatchery trays
Slika 3. Ikra potočne pastrve u ležnicama

The incubation unit has 24 standard hatchery troughs with horizontally installed incubation trays (Fig. 3). The outflow water of troughs goes to a mechanical filter (Hydrotech drum filter) for removing suspended materials. The filtered water is directed to a water reservoir tank, then pumped to an overhead tank and sprayed onto the biofilter, which is mounted to this tank (Fig. 4). About 150 litres per minute of water goes back to the incubation trays through an UV filter with a 120–watt capacity.

The fingerling production unit is installed in an area of 400 square meters. There are twenty–two fish rearing tanks (Fig. 5), holding three cubic meters each, in the system. The outflow of water from the tanks goes first to the Hydrotech drum filter and then flows to the biofilter.

The biofilter is a submerged with a volume of about sixty cubic meters. It is comprised of Bio Blocks, with the dimension of 55 x 55 x 55 centimeters. The unit surface of the Bio Blocks suitable for settling the active bacteria is 200 square units per cubic unit volume. Two 2.2 kilowatt SAER pumps, with water transferring capacity of ninety cubic meters per hour, are each used to maintain the recirculation. One of the pumps lifts the water directly to the top of a degassing tower (with a height of three meters and degassing column height of 1.5 meters) in order to remove carbon dioxide from the water and saturate it with oxygen. The other pump transfers water to the second degas-

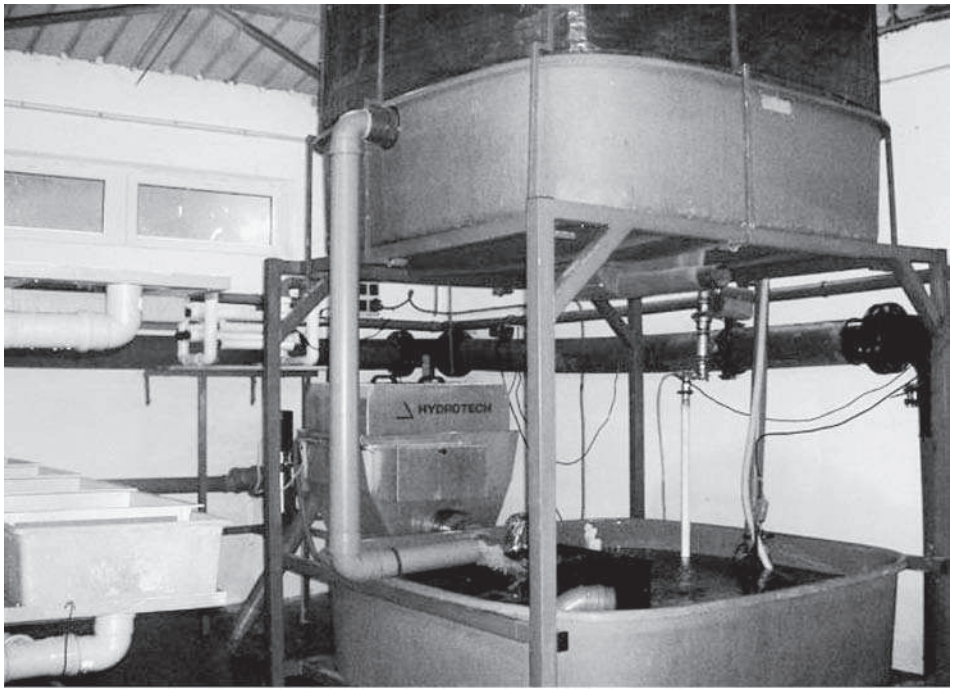

Fig. 4. The mechanical and biological purifiers and the UV filter of the incubation unit work together to sustain good water quality in the hatchery
Slika 4. Mehaničko i biološko pročišćavanje vode i UV filtar jedinice za inkubaciju u svrhu održavanja dobre kakvoće vode u mrjestilištu

sing tower through a large–capacity UV filter (for decreasing the concentration of circulating microorganisms). Two overhead tanks are located under the towers. The fish rearing tanks get water from these tanks by gravity.

The Krusnica fish hatchery has an automatic stand–by generator. For increasing the security of production, a multi–purpose alarm system was also installed. This system, in addition to local warning signals, sends telephone messages to the staff in case of electrical shortage, and abnormalities in water and air supplies. For further improving the security of the operation, an Oxygard system will also be used. The Oxyguard equipment is standard equipment on recirculation systems. The equipment constantly measures the oxygen level in the different compartments of the three water recirculating plants. It is possible to send emergency messages via telephone if the oxygen level drops under a user specified level. On a later stage when an artificial oxygen system is installed, the system will also be able to dose oxygen automatically.

The maximum allowed stocking (carrying capacity) of the fish rearing tanks is about twenty–five kilograms of fingerling per cubic meter (sev-

Fig. 5. The hatchery contains twenty–two fish rearing tanks in an area of 400 square meters
Slika 5. Mrjestilište s 22 uzgojna bazena na površini od 400 m^2

enty–five kilograms per tank), which is equivalent to about 1.6 tons of fish in the system. This quantity of fish can be produced in a five– to six–month period. However, the biofilter capacity is about 100 kilograms of feed per day, which would allow for increases in fish production, depending on the possibility of aeration (to about 2.2 to 2.3 tons per cycle). Producing up to 3.5 tons per cycle would be possible if locally generated or liquid oxygen could be supplied to the system.

The RAS technology is an energy–intensive production method (Bregnballe, 2010). By preliminary calculations, about seven kilowatts of electric energy is used for production of 1 kilogram of fingerlings in the Krusnica fish hatchery. Accounting for present prices of fingerlings and electricity, energy costs make up about 30% to 40% of the total production cost, although this figure depends strongly upon the magnitude of production.

The daily water loss from the fingerling unit (which is a consequence mainly of the backwashing of the drum filter) is about fifteen to twenty cubic meters. This water, with other wastewaters, flows out of the building. This sewage contains concentrated suspended materials and dissolved metabolites. It

will flow to a wetland system (currently in its planning phase), where active microorganisms and macrovegetation will remove dissolved metabolites and aid in mineralization of the carbon–reach materials. The cleaned water will then flow back into the river.

RESULTS

A fish hatchery is suitable for production of 250,000 to 450,000 fingerlings annually (size–dependent). Five war invalids are employed in the hatchery continuously since fish production began in November of 2008. The production technology learned by the staff abroad was adapted to the local conditions. Currently, there are 55,000 fingerlings of brown trout, eight to ten centimeters in size, in the system. These fish will be used for restocking purpose and for sale. The hatchery will have enough income for self–sustainable operation in April 2010 after selling those fingerlings which will not be used for restocking the waters of the local Sport Fishermen's Association. Since the hatchery activity has received wider publicity, anglers' interest in the River Krusnica has increased. Further increase in the number of visitors is expected after restocking the fish into the river, since the bigger fish populations will attract more and more anglers. The natural beauty of the region attracted many tourists before the war. The fly fishing–based eco–tourism was an important source of income for the local community. The local community is aware of the value of the nature of its region. They benefited from tourism before the war, and they consider tourism to be one of the most important vehicles for further development. Moreover, they possess an emotional connection to the rivers of the area, since the rivers were important playing grounds for the majority of people in their childhoods, and hundreds of people are still attached to them as anglers. For many people in Bosanska Krupa, going to the river to fish is very therapeutic. Rivers provide a refuge of quietness, something that was not available during the three and half year of shelling and shooting. Some of the citizens have expressed that walks near river, with or without fishing rods, are beneficial to their psychological health. Consequently, the progress of the project is followed by the local community, and they expect that the hatchery work will have a positive effect on the environment and their livelihood.

DISCUSSION

Two main issues now face the Krusnica fish hatchery. First, although the fish hatchery has had success in producing brown trout, grayling production has proven more complicated. Grayling seemed more sensitive to the confinement afforded by artificial habitats in a trial period, and it is likely an alternate facility will be required, at least for the healthy housing of brood stock. It is

also likely that Danube salmon will demonstrate similar habitat constraints, especially because of their large size. Second is the concern for wastewater outflow from the fishery. Although the RAS system makes this facility incredibly water–efficient, it will still see a net volumetric output of about fifteen to twenty cubic meters daily. This water, although mechanically and biologically filtered, still contains excess nitrogen and other particulates in concentrations that do not match the river's natural biogeochemistry. This imbalance, in an extreme case, could lead to complications in the river such as eutrophication, hypoxic zones, and trophic level disruptions. Hypoxia is especially dangerous to trout species (Poppe, 1999; Sedgwick, 1988), which the fish hatchery was designed to protect. Although this represents an unlikely worst–case scenario, it is still in the fish hatchery's best interests to implement a third filtration system for wastewater returning to the river.

These two issues could actually be remedied with the design of a single system: a protective, small–scale wetland. The system will be built on the downstream side of the fish hatchery, occupying a land area of about 1000 to 1200 square meters. Although still in its planning stages, the wetland is projected to provide several pools for the housing of broodstock in a more ecologically familiar environment. The series of connected pools will also be home to an array of native plant species, including aquatic vegetation, riparian trees (especially willows), and grasses. Just as in natural catchments, a wetland provides a "buffer system" for water returning to the river. Much of the volume of suspended particulates and other nutrients leaving the hatchery will be recycled in a vegetative ecological filter, bringing the water closer to the natural biogeochemistry of the river before it eventually flows back into it. Beyond the scientific function of the wetland, however, it also represents a unique opportunity for outreach. The pools and vegetation will have great aesthetic appeal. Visitors to the fish hatchery will be able to see and understand the value of ecological design in human–made systems. This is particularly important to the indirect project goal of promoting environmental consciousness to the community. In this way, the wetland could become a symbol for the entire project, showing a respect for ecological efficiency with the RAS as well as a personal connection to the local ecology of the Krusnica, which workers at the facility already demonstrate through their continued loyalty to the project.

Sažetak

MRJESTILIŠTE U OPĆINI BOSANSKA KRUPA U SJEVEROZAPADNOJ BOSNI I HERCEGOVINI: ODRŽIVI RAZVOJNI PILOT–PROJEKT

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Norveška je vlada financirala projekt GCP/BIH/003/NOR "Podrška generiranju dohotka kroz izgradnju mrjestilišta u Bosni i Hercegovini", vrijedan milijun američkih dolara, što uključuje izgradnju mrjestilišta na obalama rijeke Krušnice kako bi se kreirali poslovi i dohodak za invalide i osobe s posebnim potrebama u Bosanskoj Krupi. Mrjestilište je namijenjeno za lokalne vrste, potočnu pastrvu (*Salmo trutta m. fario*), lipljena (*Thymallus thymallus*) i mladice (*Hucho hucho*), i to za poribljavanje prirodnih voda sljevova rijeke Krušnice i Une (i šire Bosne i Hercegovine i dunavskoga slijeva), da bi se pomogla rehabilitacija riblje populacije i revitalizacija lokalnog turizma. Regionalni ured za Europu i srednju Aziju (REU) Organizacije za hranu i poljoprivredu pri Ujedinjenim narodima (FAO), sa sjedištem u Budimpešti, Mađarska, implementira projekt u uskoj suradnji s Udruženjem sportskih ribolovaca Krušnice, koja trenutačno ima 351 člana. Mrjestilište, pilot recirkulirajući akvakulturni sustav (RAS), u dolini rijeke Krušnice prvi je takve vrste u Bosni i Hercegovini. Prikladan je za proizvodnju 250 000 do 450 000 komada riblje mlađi godišnje. Pet je invalida kontinuirano zaposleno u mrjestilištu, od kada je u studenome 2008. godine počela proizvodnja ribe. Tehnologija proizvodnje naučena od osoblja u inozemstvu bila je prilagođena lokalnim uvjetima. Očekuje se da će mrjestilište biti samoodrživo u svojem radu od prodaje riblje mlađi. Otkako je aktivnost mrjestilišta stekla širi publicitet, povećao se interes ribara za rijeke Krušnicu i Unu. Buduće povećanje broja posjetilaca očekuje se nakon poribljavanja rijeke ribom, jer će veći broj riblje populacije privlačiti sve više i više sportskih ribolovaca.

Ključne riječi: mrjestilište, RAS, rijeke Krušnica i Una, održivi razvoj, potočna pastrva, lipljen, mladica, ribolov na mušicu, osobe s posebnim potrebama

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Received: 26. 2. 2010.
Accepted: 11. 6. 2010.