THE UNIVERSITY OF CALGARY

Grayling (*Thymallus thymallus*) Hatchery in the Municipality of Bosanska Krupa in northwestern Bosnia and Herzegovina: A Sustainable Development Pilot Project

by

Nedzad Ajanovic

A MASTER'S DEGREE PROJECT SUBMITTED TO THE FACULTY OF ENVIRONMENTAL DESIGN IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENVIRONMENTAL DESIGN (ENVIRONMENTAL SCIENCE)

FACULTY OF ENVIRONMENTAL DESIGN

CALGARY, ALBERTA

January 1999

ABSTRACT

Grayling (*Thymallus thymallus*) Hatchery in the Municipality of Bosanska Krupa in north-western Bosnia and Herzegovina: A Sustainable Development Pilot Project

by Nedzad Ajanovic

A Master's Degree Project submitted to the Faculty of Environmental Design in partial fulfillment of the requirements for the Degree of Master of Environmental Design (Environmental Science)

Faculty of Environmental Design, The University of Calgary

January 1999

Supervisor: Dr. Grant Ross

Keywords: Bosnia and Herzegovina, Sustainable Development, Grayling, Fisheries Management, Aquaculture, Fish Hatchery, Bosanska Krupa, River Krusnica, River Una.

In northwestern Bosnia and Herzegovina there was widespread overharvesting of the fisheries resources before the outbreak of war in 1992. Close to four years of war in the country put even greater pressure on the fisheries, mainly due to a lack of food and general lawlessness. In the post-war period, the practice of overharvesting continued, resulting in an extraordinary decline in fish populations. This project addresses factors that have contributed to the degradation of the fisheries resources in the rivers of the Municipality of Bosanska Krupa. The project proposes that a fish hatchery for European Grayling (*Thymallus thymallus*) be developed as a sustainable development pilot project for the Municipality on the River Krusnica. Besides the proposal of an environmentally sound aquaculture facility, the project recommends a fisheries management plan that addresses the following strategies and actions:

- Habitat Maintenance
- Fish Conservation
- Fish-Use Allocation
- Education
- Enforcement
- Inventory, Monitoring and Research
- Improvements in Sport Fishing Regulations.

ACKNOWLEDMENTS

There are many individuals who have assisted me on the way in successfully completing this project and I am sincerely grateful for their support. Foremost, I would like to thank my Supervisor, Professor Grant Ross, for his continuous encouragement and assistance during my study. I owe thanks to Dr. Thomas Hamor for his aquaculture and fisheries management input in this project. I am thankful to Valerie Barnes, Robert Blaxely and Christopher Finley for their contextual and editorial assistance.

I am especially grateful to my key informants, both in Bosnia and in Canada for their extremely valuable contribution to this project. I would also like to thank the support staff of the Faculty of Environmental Design, the UNOPS office in Bihac and the municipal staff in Bosanska Krupa who have always been there for me.

I am thankful to the Faculty of Environmental Design and UNDP/UNOPS for their financial assistance. Without it, the goals and objectives of this project could not have been achieved.

Finally, I would like to thank my girlfriend, Victoria Sun, for her kindness and friendship and my parents and family for their unconditional love.

CONTENTS

FIGURES AND TABLES

FIGURE:

TABLE:

ABBREVIATIONS

Bosnia	Bosnia and Herzegovina
"Divojarac"	Name of the Hunting Organization in Bosanska Krupa
EVDS	Faculty of Environmental Design
MDC	Municipal Development Committee
MDP	Master's Degree Project
NGO	Non-government Organization
FAO	Food and Agriculture Organization
FEO	Fisheries Enforcement Officer
OSF	Organization for Sport Fishermen
OWI	Organization for War Invalids
PROGRESS-B&H	Programme for Rehabilitation and Sustainable Development in Bosnia and Herzegovina
UNDP	United Nations Development Programme
UNOPS	United Nations Office for Project Services
TU	Technical Unit
"Unski smaragdi"	Name of the Environmental NGO in Bihac
"Zeleni"	Name of the Environmental NGO in Bosanska Krupa

CHAPTER 1: BACKGROUND

1.1 Former Yugoslavia and Bosnia and Herzegovina (Bosnia-Herzegovina)

The former country of Yugoslavia consisted of six Republics of which Bosnia and Herzegovina was one (Figure 1.1). The population of Bosnia and Herzegovina was 4,355,000 in 1991 (Markovic, 1991). With an area of 51,129 km^2, Bosnia and Herzegovina is larger than Switzerland (41, 290 km^2) (Colombo, 1997) and one-thirteenth of the size Alberta (661,185 km^2) (Marsh, 1985).

Figure 1.1 The former Yugoslavia (Unknown, 1981)

The Bosniacs (commonly referred to in the Western media as the Bosnian Muslims) represent the largest ethnic group in Bosnia. According to the 1991 census, they represent 43.7 percent of the overall population. The Bosnian Serbs represent 31.3 percent and the Bosnian Croats comprise 17.3 percent of Bosnia's population. Others, including mixed ethnic groups, Jews and Romas comprise the remaining 7.7 percent (Markovic et. al., 1991).

By the early 1990s, most of the Eastern and Central European countries had undergone democratization. As an outcome of this process, four of the six Republics voted for independence in referendums of succession from Yugoslavia. Sixty-four percent of voters in Bosnia and Herzegovina desired independence (Ajanovic 1998, pers. comm.). The country became independent on March 1, 1992 (United Nations, 1997). Around the same time, the Republics of Croatia, Slovenia and Macedonia also became independent nations. The remaining two, the Republics of Serbia and Montenegro, constitute Yugoslavia as it stands today.

Although often referred to as only Bosnia, the country's full name is actually Bosnia and Herzegovina. Bosnia stands for the northern region, whereas Herzegovina represents the southern part of the country. For convenience, I will use just Bosnia in referring to the whole county in this project.

After declaring independence, Bosnia was recognized as an independent country by numerous nations around the world including Canada and the United States. It became a full member of the United Nations on May 22, 1992 (United Nations, 1997).

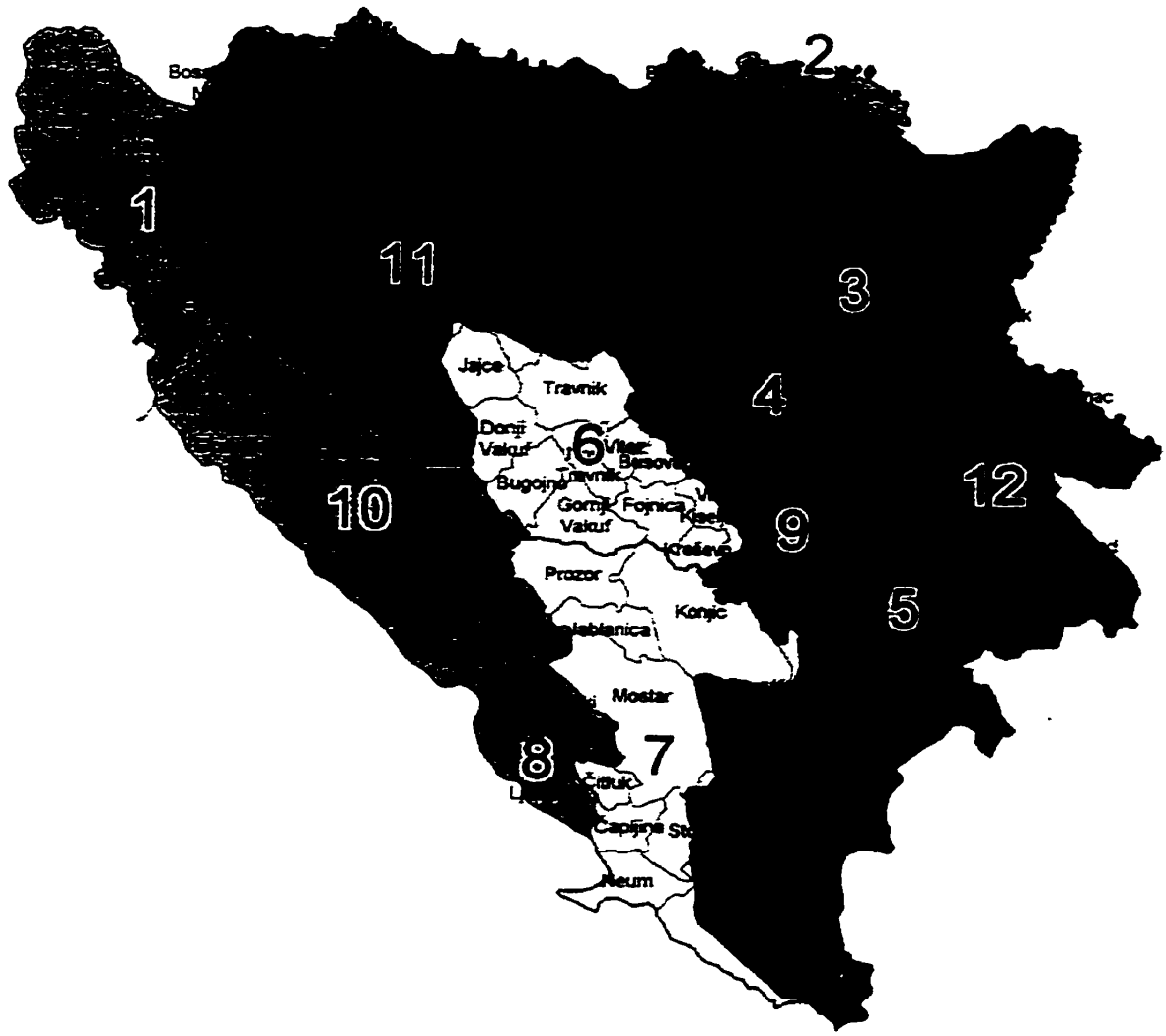
1.2 War in Bosnia, April 1992 - December 1995

The succession of the Republic of Bosnia and Herzegovina from the former Yugoslavia caused the Yugoslav Army, which was at the time loyal only to Belgrade (the capital of Serbia), to invade Bosnia militarily. The army rationalized the invasion of Bosnia by claiming they were protecting the interests of the Serb minority living in Bosnia. Two years into the war with the Yugoslav forces, the Bosnian government was attacked by the Croatian Army (until that point an ally of Bosnia) and the Croats justified their invasion in the same way as the Serbs (Denitch, 1994). At that time, the presidents of Yugoslavia and Croatia decided in secret meetings to divide Bosnia between them (Denitch, 1994).

The war in Bosnia lasted for close to four years. Fifty percent of the population (over two million people) were displaced and made refugees by the Yugoslav and Croat armies through systematic "ethnic cleansing". Many of these people found refuge in other countries. According to the statistics from the United Nations High Commissioner for Refugees (UNHCR), there were 1,319,250 Bosnians living in other European countries in June 1996 (UNHCR, 1996). The rest of those displaced found refuge in other parts of the world (the United States, Canada and Australia) or became refugees within the country in the areas dominated by their own ethnic group. In this war, more than 200,000 people were killed, most of them civilians including children and the elderly.

1.3 Dayton Peace Agreement

In December 1995, the warring parties in the Bosnian conflict were forced by the United States and the international community to negotiate a peace agreement. This agreement was signed by all of the parties involved in the Bosnian war. The agreement was negotiated in Dayton, Ohio, and is thus referred to as the Dayton Agreement. This agreement guaranties that Bosnia and Herzegovina stays as one country, but divides its territory into two entities. One entity is called the Republic of Srpska where the majority are Bosnian Serbs and the other entity is called the Federation of Bosnia and Herzegovina where the majority are Bosniacs and Bosnian Croats. The Agreement granted the Republic of Srpska 49% of the overall Bosnian territory and the Federation of Bosnia and Herzegovina 51% (Figure 1.2). The Dayton Agreement calls for freedom of movement throughout the country. It also calls for the return of refugees to their original homes.



Cantons in the Federation of Bosnia and Herzegovina

1. Una-Sana
2. Posava
3. Tuzla-Podrinje
4. Zenica-Doboj
5. Upper-Drina
6. Central-Bosnia
7. Neretva
8. West-Herzegovina
9. Sarajevo
10. West-Bosnia

Regions of the Republic of Srpska

11. Banja Luka (Western)
12. Pale (Eastern)

Figure 1.2 Bosnia and Herzegovina (PROGRESS and IMG, 1996)

1.4 International Aid Organizations

Throughout the war in Bosnia, numerous UN and other international aid organizations began operating. While the fighting was going on, most of these organizations concentrated their efforts on caring for civilians and refugees by delivering food and medicine. At the end of the war, international aid organizations gradually switched their aid policies from humanitarian to development. The international community has pledged large financial sums after the war, especially in the areas of health, education, power and transportation (PROGRESS Bosnia & Herzegovina, 1996). Some of the aid organizations operating in Bosnia include: United Nations Development Programme (UNDP), United Nations Office for Project Services (UNOPS), World Bank, European Union, USAid, United Nations High Commissioner for Refugees (UNHCR), International Organization for Migration (IOM), Solidarites, Handicap International, National Governments and International Management Group (IMG).

1.5 Cantons

The Federation of Bosnia and Herzegovina consists of ten federal units that are called Cantons (Figure 1.2). Cantons are administrative units that have a high level of self-rule. The Cantons are responsible for establishing, organizing and implementing their own police force, educational policy, culture, housing, public services, local land use and zoning, local business and charitable activities, local energy production facilities, radio and TV policy, social welfare policy, tourism and financing of the local government. The Federation and the Cantons may share responsibilities in the enforcement of human rights, health policy, environmental policy, communication and transport infrastructure, Social Welfare policy, rules on citizenship, immigration and asylum, tourism and use of natural resources (University of Sarajevo – Faculty Institute of Economics, 1997). Cantons and the Federation may also delegate some of their responsibilities to the municipalities. Similarly, the municipalities may delegate some of their responsibilities to either the Federation or Cantons (University of Sarajevo – Faculty Institute of Economics, 1997).

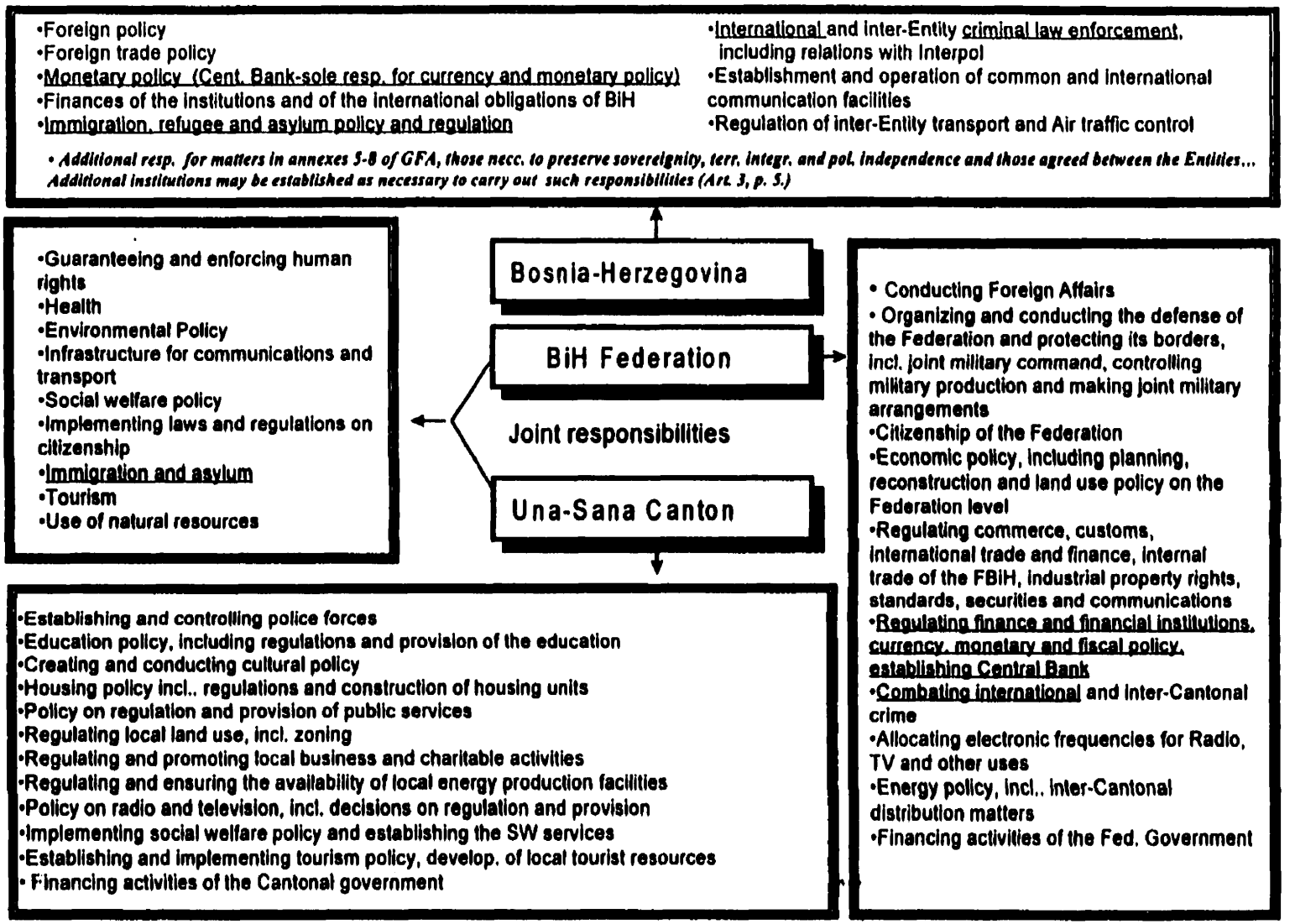


Figure 1.3 Relationship Between Bosnia and Herzegovina, B&H Federation and Una-Sana Canton and Their Responsibilities (University of Sarajevo, Faculty Institute of Economics, 1997).

1.6 Una-Sana Canton

The Cantons are either named after the main city of that federal unit or after the regional geographic features. The Una-Sana Canton gets its name from the two main rivers of the region (University of Sarajevo – Faculty Institute of Economics, 1997).

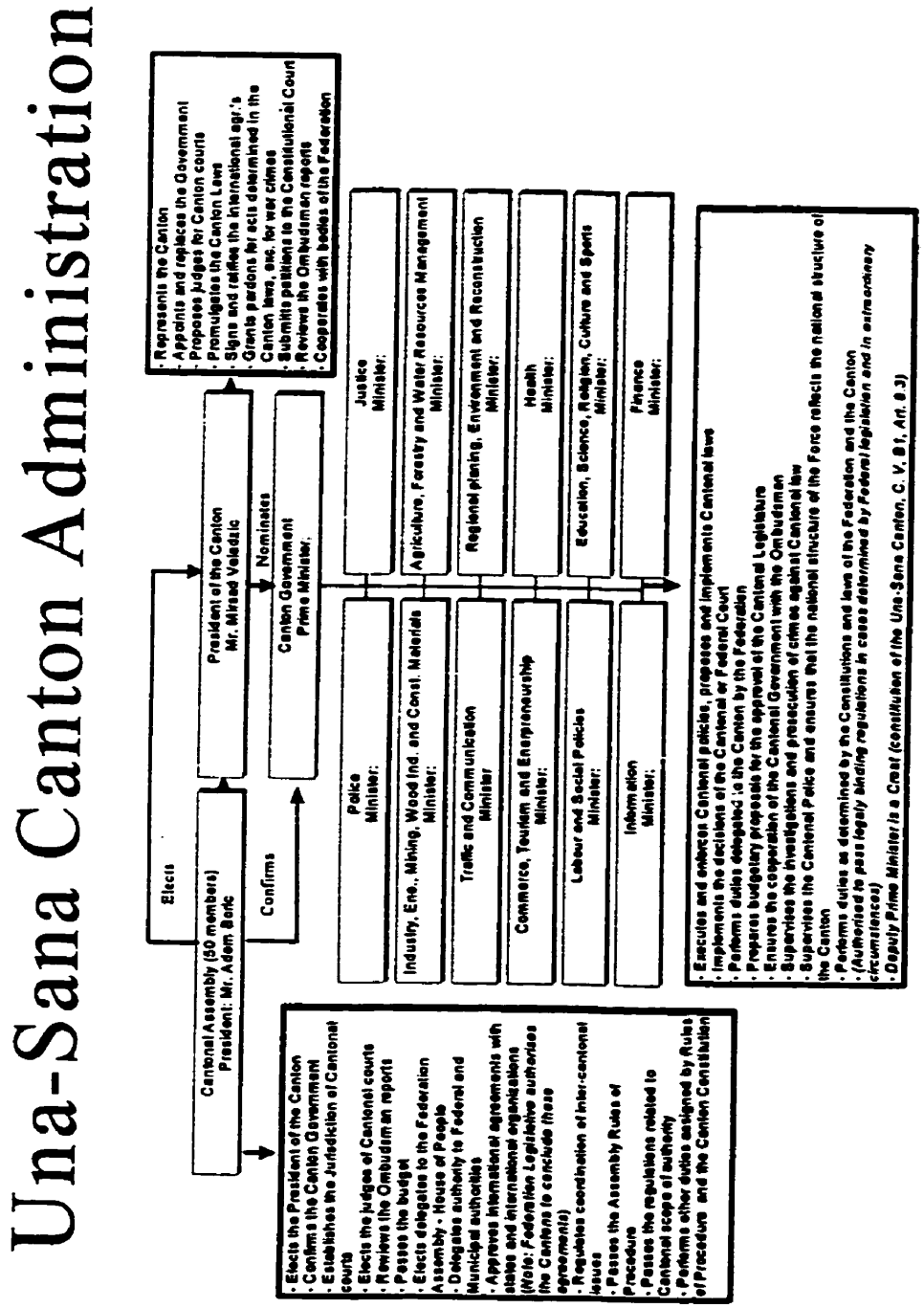


Figure 1.4 Una-Sana Canton Administration (University of Sarajevo – Faculty Institute of Economics, 1997).

Ministries of the Una-Sana Canton

Police	Finance	Justice	Industry, Energy, Mining, Wood Industry and Production of Construction Material	Transport and Communication	Agriculture, Forestry and Water resources
↳ Cantonal and public order and security ↳ Protection of human rights, life and security ↳ Prevention of crimes ↳ State borders and traffic ↳ Residence and travel of foreigners ↳ Organization, arming and education of the Police force ↳ Travel and identification documents, archives of birth and marriage cert. ↳ registration of vehicles etc.	↳ Financing public expenditures ↳ Tax system and policy ↳ Forming and financing of development funds ↳ Preparation and supervision of the budget and Canton funds ↳ System of solidarity ↳ Coordination of activities of commercial banks in economic investments ↳ Insurance system, taxes, gambling ↳ System of solidarity	↳ Organization, staffing supervision and logistics for Cantonal and Municipal judicial administration ↳ Implementation of amnesty and pardon ↳ Supervision of Cantonal administration ↳ Proposals for principles of local self-administration ↳ Supervision of correctional facilities ↳ Other administration not under any other Ministry	↳ Establishment and reconstruction of industrial capacities ↳ Securing production of deficient products ↳ Policy on Energy ↳ Reconstruction of energy product. facilities ↳ Economic exploitation of natural resources ↳ Industrial property rights ↳ Inspect. in production of power, steam-boilers and mining	↳ Planing of construction and reconstruction, develop. and maintenance ↳ Research and develop. ↳ Telecommunication ↳ planning frequencies for the Canton ↳ Operating permits for radio stations ↳ Road, Rail, Air, Pipe-line and Postal traffic ↳ Air-traffic control ↳ Cargo services ↳ Creation of public corporations ↳ Inspection and supervision	↳ Agricult. production, use of arable land ↳ Seeds and seedlings ↳ Diseases protection ↳ Cattle, animal health, food control, cattle feed and water ↳ Exploitation of forests, reforestation ↳ Hunting and Fishing ↳ Agricultural and veterinary inspections ↳ Water resources control and management ↳ Inspection supervision of hunting and fishing
Regional planning, Environment and Reconstruction	**Commerce, Tourism and Enterpreneurship**	**Health**	**Labour, Social Policy, Refugees and Displaced Persons**	**Education, Science, Religion, Culture and Sports**	**Information**
↳ Land-use planning on Cantonal level and coordination of municipal plans ↳ Reconstruction of war-damaged facilities and building of new infrastructure network ↳ Demands for reparations ↳ Coordination of reconstr. planing and assistance to municipalities ↳ Regulations for building and construction ↳ Houses and buildings ↳ Housing relations ↳ Public Utilities ↳ Environment protection ↳ Directorate for geodetic and property law	↳ Traffic of goods and services in the Canton ↳ Tourism, services, reconstruction and development ↳ Craftsmanship ↳ Functioning of the market of goods and services ↳ Promotion of tourism ↳ Level of market supply ↳ Prices of goods and services ↳ Consumer protection ↳ Redirecting the Cantonal funds and reserves ↳ Independent market activities ↳ Inspection supervision	↳ Health protection system and reconstruction of capacities ↳ Proposing the financing of and handling of the Health Insurance funds ↳ Work of health institutions ↳ Planning the health supplies ↳ Medical Goods Reserves ↳ Health-inspection of food and items for general use ↳ Prevention of diseases ↳ Sanitary supervision of State borders ↳ Protection from ionization ↳ Education and specialist training ↳ Expert supervision of health institutions	↳ Labour protection ↳ Retirement and disability insurance ↳ Protection of civilian victims of war ↳ Family protection ↳ Social protection ↳ Promotion of humanitarian activities and services ↳ Financing and handling of retirement, disability and social insurance and employment funds ↳ Planing and distribution of humanitarian aid and cooperation with donors ↳ Inspection supervision ↳ Directorate for R&DPs	↳ Pre-school, primary, secondary and higher ed. ↳ Curriculum for pre-school ↳ Plans and programs for primary and secondary ed. ↳ Standards and norms ↳ Construction and reconstruction of facilities, cultural objects, sports facilities and sacral objects included in cult. heritage ↳ Development of scientific research ↳ Cultural heritage ↳ Culture, film, theater etc. ↳ Civil societies in fields of science, education, culture and sports ↳ Financing and supervision	↳ Development and function of the system of inform. ↳ Work of public corporations founded by the Canton ↳ Registration and records of all inform. published or broadcast in the Canton ↳ Accreditation of journalists, press monitoring ↳ Informs the public on work of Cantonal bodies ↳ Publications and documentation of events in the Canton ↳ Imports foreign and exports local papers

Figure 1.5 Ministries of the Una-Sana Canton (University of Sarajevo – Faculty Institute of Economics, 1997).

Two ministries of the Una-Sana Canton, to which this proposed project is directly relevant are the:

- Ministry for Agriculture, Forestry and Water Resources
- Ministry of Regional Planning, Environment and Reconstruction.

Ministries to which this proposed project is indirectly relevant are the:

- Ministry of Commerce, Tourism and Enterpreneurship
- Ministry of Education, Science, Religion, Culture and Sports
- Ministry of Information (University of Sarajevo – Faculty Institute of Economics, 1997).

All of the above ministries are stakeholders in this proposed project.

1.7 Municipalities

The Federal Constitution of Bosnia and Herzegovina gives power to municipalities in exercising self-rule in local matters. The Law on Fundamentals of Local Self-Government, adopted in November 1995, defines the self-government responsibilities of municipalities in the following ways:

- ensure conditions for the respect and protection of human rights and fundamental freedoms, in accordance with the Constitution
- provide for the local needs of the population in the spheres of: child care, education and upbringing; labor and employment; social welfare; culture, physical education and sports; protection of animals and vegetation
- conduct urban planning and housing policy relevant to the Municipality and its development
- administer municipal property
- perform public utility and other communal services and be responsible for the local road infrastructure
- provide conditions for the operation of local radio and TV stations, in accordance with the Law
- administer tourist resources of the Municipality
- ensure the use and administration of local construction locations

- ensure public order and peace
- administer other issues in accordance with the Constitution and laws (Law on Fundamentals of Local Self-Government, 1995).

Direct participation of citizens in the decision-making process is outlined in law (Law on Fundamentals of Local Self-Government, 1995). The decision-making process of participation may include referenda, public assemblies and other forms of citizen participation (University of Sarajevo – Faculty Institute of Economics, 1997).

Municipalities may engage with other municipalities to perform tasks that are of mutual benefit and interest. Municipalities may also join local units of any international association and cooperate with local units of other nations (University of Sarajevo – Faculty Institute of Economics, 1997).

Municipalities are composed of the following bodies:

1. Municipal Assembly – legislative body of the Municipality: elects the Municipal Executive, establishes the administrative bodies upon the proposal of the Municipal Executive, enacts regulations and ordinances within the scope of municipal responsibility, prepares and approves the Municipal Charter and approves the budget.

2. Municipal Executive – executive authority of the Municipality: represents the Municipality, proposes the establishment of the municipal administration and is responsible for its work; enforces and implements municipal policies, regulations and ordinances; ensures the cooperation of the municipal administration with the ombudsman and reports to the Assembly.

3. Local Communities – a form of direct citizen participation in the process of decision making on local issues.

(University of Sarajevo – Faculty of Economics, 1997).

In the Municipality of Bosanska Krupa, the Municipal Development Committee (MDC) – which will be discussed later in the project, has been developed under Local Communities (item 3 above). It represents this form of direct citizen participation in the process of decision making on local issues affecting the Municipality.

1.7.1 Municipalities of Una-Sana Canton

The Una-Sana Canton has eight municipalities which include: Bihac, Cazin, Velika Kladusa, Buzim, Bosanska Krupa, Sanski Most, Kljuc and Bosanski Petrovac (Figure 1.2). All of the municipalities are named after their main city or town.

1.7.2 Municipality of Bosanska Krupa

The town of Bosanska Krupa lies in northwest Bosnia, in Una-Sana Canton, and on the eastern (right) bank of the River Una. The municipality covers an area of 556 km^2, down from a pre-war area of 778 km^2 (PROGRESS-BiH-A, 1997). The Dayton Agreement changed the land areas of some municipalities in Bosnia to accommodate the 51%-49% land ratio between the Federation of Bosnia and Herzegovina and the Republic of Srpska. The town used to be a major node for both the railway system (on the Zagreb-Split and Bihac-Banja Luka-Sarajevo lines) and the road network (PROGRESS-BiH-A, 1997). From a pre-war population of 58,212 inhabitants (73% Bosniacs, 23% Serbs and 4% other ethnic groups), the population has shrunk to a current 27,336 (99% Bosniacs) (PROGRESS-BiH-A, 1997). In 1997, there were 4040 internally displaced people recorded in the municipality (PROGRESS-BiH-A, 1997). However, a large number of returnees were expected in 1998 and are expected in 1999, increasing the pressure on already strained municipal services and resources.

Bosanska Krupa is the most damaged municipality in Una-Sana Canton, ranking as the third most destroyed municipality at the national level, with 90% of its buildings heavily damaged or destroyed as a result of close to four years of warfare (PROGRESS-BiH-A, 1997). The municipality had four main industries before the war, employing 2600 people in timber processing, metal works, vehicle manufacturing and textiles (PROGRESS-BiH-A, 1997). At present, some facilities exist for mining bauxite and manganese in the area. However, industrial infrastructure has been almost completely leveled. Total damage is estimated to be in the hundreds of millions of US dollars. The actual labor force is estimated at 12,400 people, with only 700 employed (PROGRESS-BiH-A, 1997).

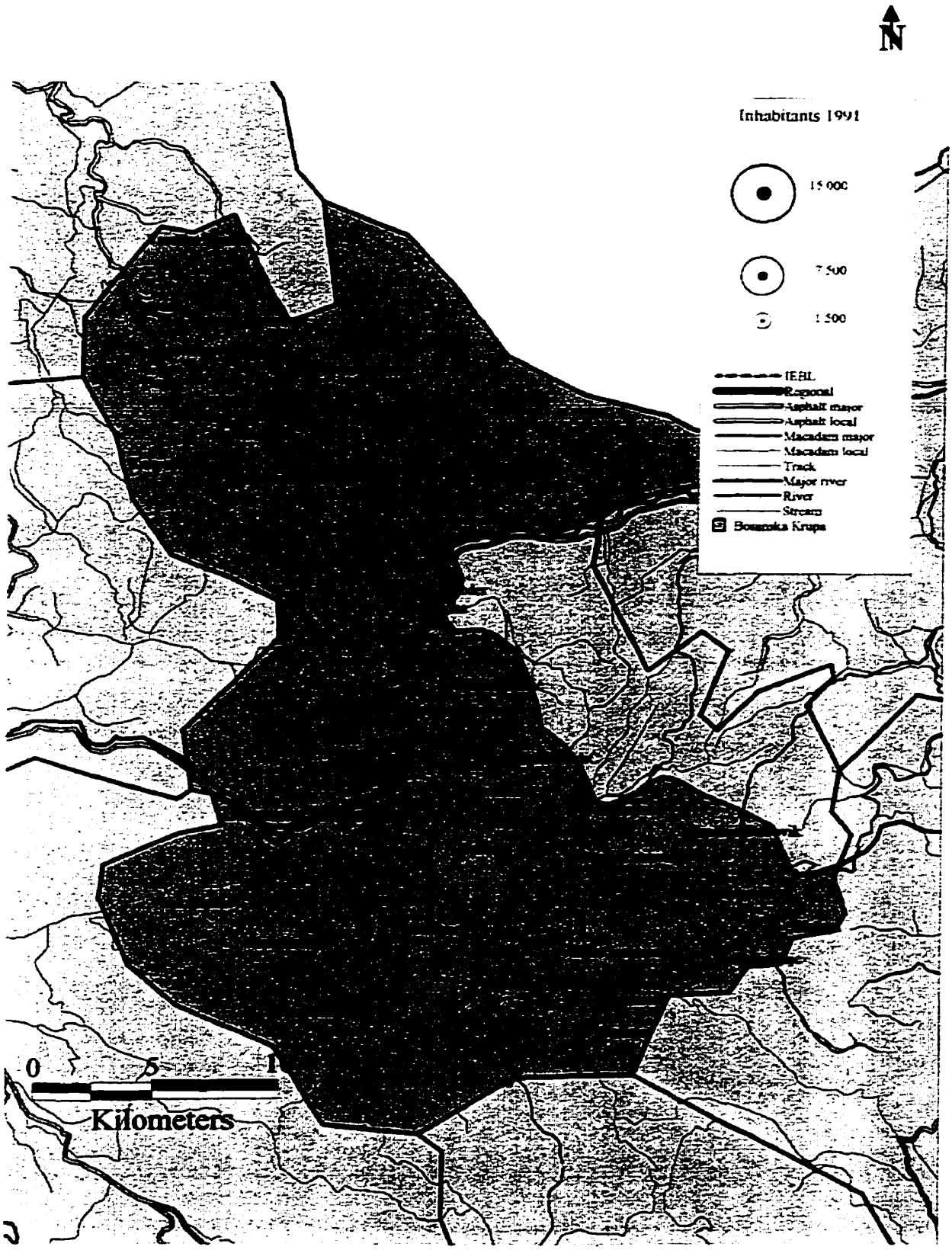


Figure 1.6 Municipality of Bosanska Krupa (PROGRESS and IMG, 1996).

The pre-war Municipality had 38 primary schools and two high schools, with enrollment of around 10,000 students per. There are currently three primary schools with enrollment of 2321 students, and two high schools with 747 students in total year (University of Sarajevo – Faculty Institute of Economics, 1997). Estimated damage to the educational facilities fall mostly into the 0-15% category, with six primary schools and one secondary school being damaged more severely (five schools in the 15-40% category, one in the 40-60% category and one high school in the 60%+ category) (University of Sarajevo - Faculty Institute of Economics, 1997).

The Cultural Center building is currently not in use, having sustained approximately 30% damage. The Center in Bosanska Otoka is also not in use, having sustained more than 40% damage. The City Library falls into the first category of damage (12%) and is currently working (University of Sarajevo - Faculty Institute of Economics, 1997).

A health care center with 35 doctors was active in 1991. Today, there is a health center, with eleven doctors and 67 nurses, and six doctor's consultation rooms with two doctors (two doctor's consultation rooms are covered by visiting doctors) and seven nurses. The Center and the doctor's consultation room in Mahmici are being repaired by the HELP/International Management Group (IMG) and the other doctor's consultation room is waiting for a sponsor (University of Sarajevo - Faculty Institute of Economics, 1997).

Of the 7204 housing units, 3602 are damaged but in use, and 2521 are at present not in use (University of Sarajevo - Faculty Institute of Economics, 1997).

Figure 1.7 Town of Bosanska Krupa (Saric 1997, pers. comm.).

1.8 UNDP - UNOPS Collaboration in Northwestern Bosnia

The fieldwork for this Master's Degree Project (MDP) lasted six months, from June to December 1997. During this time, I worked as an Environmental Science Intern for an aid organization called UNOPS (United Nations Office for Project Services). My Terms of Reference included the following tasks:

- Assist the Municipal Development Committees (MDCs) in the target municipalities of PROGRESS with the assessment of environmental and natural resource management situations

- Assist the MDCs with the identification of projects in environmental and natural resource management

- Train PROGRESS and the municipal Technical Unit (TU) staff in Environmental Impact Assessment

- Assist the TU with the formulation of projects in environmental and natural resource management.

UNOPS is an independent organization in the United Nations, but in the past it was under the umbrella of UNDP (Cluckers 1997, pers. comm.) UNOPS still gets a lot of its financial support from UNDP's sources of funding (Cluckers 1997, pers. comm.).

The UNOPS head office in Bosnia is in the capital city of Sarajevo. Their aid work at the time of my internship was concentrated in Bosanska Krajina, a region of northwest Bosnia that lies in both entities of the country (i.e. the Federation of Bosnia and Herzegovina and Republic of Srpska). UNOPS had established its regional offices in this region, one in each entity. The UNOPS regional office in the Federation of Bosnia and Herzegovina is located in Bihac, while the one in the Republic of Srpska is located in Banja Luka. Both offices are responsible for doing work in the two neighboring municipalities. The office in Bihac was responsible for the nearby municipalities of Bosanska Krupa and Kljuc. The office in Banja Luka was responsible for the nearby municipalities of Bosanski Novi and Ribnik. UNOPS operates in these municipalities through the Programme for Rehabilitation and Sustainable Socio-Economic Development in Bosnia & Herzegovina (PROGRESS). PROGRESS was proposed by the UNDP and

implemented by the UNOPS (PROGRESS Bosnia & Herzegovina, 1996). The objectives of the PROGRESS program are:

- To help re-establish basic requisites of economic growth and job creation, and to strengthen local managerial and delivery capacities in the social and economic sectors through simultaneous and interrelated efforts

- To advance the peace process at the local level through enhancement of decision-making capacities in a context of economic recovery

- To facilitate the return and reintegration of displaced populations and demobilized combatants, as well as their participation in civic life at the local level, thus complementing efforts currently undertaken by UNHCR and other agencies

- To support the efforts of governmental authorities in promoting democratic institutions and decentralization policies by strengthening local economic and administrative capabilities and promoting local participation (PROGRESS Bosnia & Herzegovina, 1996).

The intention of PROGRESS is to support a democratic process whereby the people who are directly affected can express their views on problems that concern them. PROGRESS encourages interrelationships and cooperation among various sectors of the civil society and fosters a positive relationship with the government authorities (PROGRESS Bosnia & Herzegovina, 1996).

1.9 The Municipal Development Committee (MDC)

The Municipal Development Committee (MDC) is a forum established at the local level in the spirit of genuine dialogue, participation, solidarity and equity. Its purpose is to identify priorities, encourage local initiatives and mobilize local and external resources needed for the sustainable social, economic and cultural recovery of the community (PROGRESS-BiH-B, 1997).

The mobilization of resources, both financial and human, is necessary for the success of sustainable development. The mobilization of human resources entails the mobilization of technical resources from the local government, the private sector and civil society (PROGRESS-BiH-B, 1997).

In the Municipality of Bosanska Krupa, a number of initiatives are currently ongoing, supported by the national government, the cantonal/regional authorities and/or international organizations. These ongoing initiatives address the resettlement of refugees and internally displaced people, as well as reconstruction and rehabilitation of different sectors (PROGRESS-BiH-B, 1997).

All of these initiatives are urgent, interrelated and interdependent and in many cases have different objectives, methodologies and expected results. Different local actors are involved in their identification, formulation, implementation, monitoring and evaluation. Most of the time, local actors have different agendas, mandates, roles and responsibilities. In many cases, these ongoing initiatives are often managed in isolation of one another as stand-alone initiatives, without taking into consideration other related and dependent aspects of the same problem (PROGRESS-BiH-B, 1997).

The MDC has a key role to play in guiding, orienting and articulating the contributions of various local actors, including the international organizations, toward a comprehensive and coherent framework. Providing the MDC with the mandate of articulating and coordinating all ongoing initiatives at the local level would result in great achievement for the empowerment of the local institutional fabric (PROGRESS-BiH-B, 1997).

The MDC is composed of approximately 25 people in the municipalities where UNOPS operates. The MDC teams emerge by having the UNOPS representatives approach the mayors of the municipalities. A mayor is asked to suggest two influential people in the municipality who are interested in working in a team for the good of the municipality. The two people suggested by the mayor are each approached and asked to suggest two other people. The process is repeated until about 25 people are chosen. International

organizations are more comfortable working with diverse teams of local citizens (with different backgrounds and interests) because they feel that with a wider and more diverse representation of the local people, the development priorities of the municipality could better be addressed (Reteire 1997, pers. comm.). Furthermore, with a MDC-like structure in a municipality, corruption is more likely to be avoided (Reteire 1997, pers. comm.).

The MDC of Bosanska Krupa consists of numerous local citizens in the professions of: mayor, teacher, engineer, policeman, economist, social worker, geologist, medical doctor, and others. The list of all MDC members in the municipality of Bosanska Krupa can be seen in Appendix A. Six of the 25 MDC members in Bosanska Krupa are women.

The credibility of the MDC as a consensus-building mechanism will progressively increase as its technical competency increases. The development of the capacity of the Technical Unit (TU) is of great importance, especially in information analysis and management. With the help of the TU, the MDC would be in better position to carry out its primary mandate of programming and managing an integrated development strategy at the local level (PROGRESS-BiH-B, 1997).

1.10 Technical Unit (TU)

The Technical Unit (TU) is a department of the municipal government. Its operational costs are covered by the municipal budget (Cluckers 1997, pers. comm.). The TU was established by the Municipality and assisted by the UNOPS as an information management group providing technical services to the MDC. The TU collects, organizes and analyses, through a reliable computerized information system, all data and indicators concerning the socio-economic life of the Municipality. This information management role is essential to enable the MDC to implement the local development initiatives into a comprehensive strategic framework. The TU is a non-profit entity, but notwithstanding this, it may generate resources that are necessary to meet its operating costs and expenses (PROGRESS-BiH-C, 1997).

The terms of reference and the operating procedures of the TU are determined by the MDC in conjunction with the relevant municipal authority. The staff members of the TU are determined by the MDC in conjunction with the relevant municipal authority. The staff members of the TU are not members of the MDC, although they can attend meetings of the MDC in an advisory capacity (PROGRESS-BiH-C, 1997).

The TU is composed of at least three people. It is coordinated by a manager selected by the MDC in close consultation with the relevant municipal authority. The manager should preferably be an economist, a development planner or an architect. The two other members of the TU should preferably have complementary backgrounds such as civil engineering, law or education. All staff members of the TU are employees of the Municipality and remain on the municipal payroll (PROGRESS-BiH-C, 1997). In Bosanska Krupa, the TU consists of three members, an economist, an industrial designer and an engineer (Appendix B).

The objectives of the TU are to:

- develop and maintain the Municipal Information System on a sustainable basis
- develop local capacity in project formation, monitoring and evaluation (PROGRESS-BiH-C, 1997).

In order to achieve these objectives, the TU would:

- liaise with the respective municipal departments for gaining necessary information
- liaise with the relevant cantonal/regional departments for gaining necessary information
- compile, analyze, and file all available information towards the establishment of the Municipal Information System
- regularly update the Municipal Information System on:
  1. the Municipal Data Base containing: maps, socio-economic indicators, descriptions of various services, the directory of all local actors
  2. the Municipal Development Programme Monitoring System containing the information on all ongoing initiatives.

- process and finalize project documentation at the request of the MDC
- consolidate the projects into a Municipal Development Programme at the request of the MDC
- support the MDC by maintaining their specific data requirements
- support the MDC in the preparation of any relevant information to be disseminated among local actors
- train various local actors in project formulation, monitoring and evaluation
- advertise and publish the activities undertaken under the umbrella of the MDC
- generate, as far as possible, resources to meet its running and expansion costs on top of the existing budget (i.e. a percentage on funded projects and consulting services) (PROGRESS-BiH-C, 1997).

1.10.1 Environmental Data

In collaboration with the TU, collection of data in the area of environmental and natural resources was undertaken in:

- forestry
- wildlife
- fisheries
- agriculture
- waste
- land mine hazards

The collected data were stored in the databases of two TUs (Municipalities of Bosanska Krupa and Kljuc) and the UNOPS office in Bihac. Some of the collected data were used in the development of this project.

1.10.2 Environmental Project Briefs

Three projects in the overall area of environmental and natural resource management that were recommended to PROGRESS-BiH in a collaborative decision of the MDC, the TU and the Municipal Executive Office:

- Cleaning of garbage from the river bed and banks of the Unadzik (channel of the River Una)
- Eco-tourism complex at the source of the River Krusnica
- Development of a Grayling (*Thymallus thymallus*) hatchery on the River Krusnica.

Project briefs were produced with the help of TU.

1.11 Environmental NGO in Bosanska Krupa

In the municipality of Bosanska Krupa, there is an established environmental non-government organization called "Zeleni" (Komic 1997, pers. comm.). "Zeleni" in the Bosnian language means "green". Their involvement in municipal environmental issues dates well before the beginning of the war (1992). In the past, the organization had championed numerous environmental activities in the municipality, including: environmental education programs for primary schools, shore clean-up of the River Una, water-quality monitoring of the municipal watershed, protest on the operation of a hog farm because of its extensive effluent discharge to waterways and establishment of collaboration links with other environmental NGOs in northwestern Bosnia (Komic 1997, pers. comm.).

"Zeleni" also collaborates with the Organization for Sport Fishermen (OSF) in monitoring the water quality of the municipal waterways. Very important roles can be played by "Zeleni" in this proposed sustainable development pilot project. One of these roles can be educational, enhancing the environmental awareness of the general public and school children as it relates to the proposed project. Their role in the project is important especially if done in collaboration with the OSF, the Organization for War Invalids (OWI), MDC, TU and other stakeholders within the local municipal government.

1.12 Project Formulation

It is important to note that projects in the area of environmental and natural resources management were not a priority according to the MDC, the TU, and the Municipal Executive Office (Harbas, F. 1997, pers. comm.). There were more pressing issues in the municipality such as the rebuilding and reconstruction of destroyed houses, hospitals and schools. Besides such basic needs and priorities, the local stakeholders in the municipal government are also interested in fixing destroyed infrastructure such as the electric grid, water lines, sewage lines, roads and telephone lines. This is crucial in facilitating the return of refugees to their homes. The proposed projects in environmental and natural resources management are important, but the right time for their implementation may be in the future, once the basic needs of citizens are fulfilled (Harbas, F. 1997, pers. comm.).

Upon returning to Calgary after the completion of my MDP fieldwork in Bosnia (May – December 1997) (also an internship with the UNOPS), a meeting was held with my MDP committee. During that meeting, my advisors suggested that I focus the MDP on a specific project that emerged from my fieldwork. The objectives of my earlier MDP proposal were accomplished in Bosnia and the information was stored in the databases of the TU in the Municipalities of Bosanska Krupa and Kljuc, as well as the databases of the UNOPS office in Bihac.

It is important to note that the goal and objectives of the revised MDP still fall into the overall goal and objectives of the previous MDP proposal. The revised MDP is more focused by providing a specific pilot project proposal and, as such, has a better chance of being implemented on the ground.

With the encouragement of my MDP advisors and the stakeholders in the Municipality of Bosanska Krupa, I decided to focus in on the proposal of a grayling (*Thymallus thymallus*) fish hatchery project. Personally, I feel that if implemented, the project will accomplish more than the other two potential projects in terms of sustainable

development in the municipality. Furthermore, my interests and expertise are closer to this project than the others.

CHAPTER 2: OBJECTIVES AND RATIONALE

The goal of this project is to develop a sustainable development project that can be carried out in northwestern Bosnia. When implemented, it would help the local residents of the Municipality of Bosanska Krupa recover from the ravages of close to four years of war. The project would also contribute to a sustainable development strategy for the Una-Sana Canton and the nation as a whole.

The objectives include:

- to address factors that have contributed to the degradation of fisheries resources in the rivers of the Municipality of Bosanska Krupa
- to propose a grayling (*Thymallus thymallus*) hatchery on the River Krusnica as a sustainable development project for the Municipality of Bosanska Krupa
- to address possible means to achieve sustainable fisheries management in the Municipality of Bosanska Krupa.

2.1 War Invalids and Employment Opportunities

In the Municipality of Bosanska Krupa there are 790 war invalids (Harbas F. 1997, pers. comm.). These war invalids have formed their own organization in the municipality, called the Organization for War Invalids (OWI) (Harbas H. 1997, pers. comm.). This population is one of the most disadvantaged in Bosanska Krupa. The organization engages in activities in which the invalids are able to work in order to assist themselves in improving their financial situation, which in turn allow them to further their treatment and rehabilitation. According to Harbas H., the majority of war invalids are fishermen and have expressed interest in helping to develop and run the proposed fish hatchery (Harbas H. 1997, pers. comm.). Many of the war invalids are also influential members in the Organization for Sport Fishermen (OSF). The proposed fish hatchery project could provide both full-time and part-time employment opportunities for this disadvantaged group of citizens.

2.1.1 Tying of Artificial Flies for Angling

War invalids receive some financial allowance from the government, equivalent to about $100 CDN per month. This amount is barely enough to buy the basic food items for survival.

It is recommended that the proposed aquaculture facility be run by the OWI. Many of the invalids are capable of performing the tasks of running the proposed aquaculture facility. There are also war invalids who cannot perform tasks needed to run the aquaculture facility, such as those people who have lost their legs from land mine explosions. Some of these people may be interested in learning how to tie artificial flies, which could be sold through their own OWI. Training seminars in fly-tying (possibly from OSF) could be organized for the interested war invalids. These flies could be sold commercially, locally and beyond, to further help improve the present economic situation of the war invalids.

2.2 Fish for Food

The socio-economic situation for the majority of people in Bosanska Krupa is very grim. The region's industrial infrastructure was almost completely leveled by the war. Total damage is estimated at hundreds of millions of US dollars. The actual labor force is estimated at 12,400 people, with only 700 employed (University of Sarajevo - Faculty Institute of Economics, 1997; PROGRESS-BiH-A, 1997). For the vast majority, fish is a major source of dietary protein. Many families count on their immediate family members to catch fish for food. The establishment of a small-scale and environmentally conscious fish hatchery near Bosanska Krupa would help raise fish that could then be stocked in the River Krusnica and other waterways in the municipality. Stocking would increase the number of fish in the municipal waterways and thus allow those who depend on fish for food to have a better diet.

2.3 No Grayling Fish Hatchery in Bosnia

There is not a single grayling fish hatchery operating in Bosnia and Herzegovina (Brankovic 1997, pers. comm.). The closest fish hatchery that produces grayling fry is in Slovenia. Before the break-up of Yugoslavia, fishing organizations in Una-Sana Canton

used to buy grayling fry from Slovenia. It took them only five hours to transport the fry from Slovenia. Today, there are two border crossings, one between Slovenia and Croatia and the other between Croatia and Bosnia. Trucks are usually kept at the border crossings for hours at a time. Presently, if the organizations for sport anglers from Una-Sana Canton are to get the grayling fry from Slovenia, most of the fry would die because of the extended transportation time which may last for more than three days.

2.4 Cost of Fry and Transportation

One of the reasons for not stocking streams with fry within the municipality of Bosanska Krupa is because it is very expensive to buy and transport the needed fry for such purposes. The closest brown trout fish hatchery is at the source of the River Klokot, near Bihac. This fish hatchery is about 50 km away from Bosanska Krupa and is presently the only fish hatchery operating in the Una-Sana Canton. It is small in size and does not produce enough fry for all nine municipalities in Canton. In the best interest of rehabilitating the municipal waterways by stocking, each municipality should have its own small-scale fish hatchery in operation.

2.5 Pilot Project with Future Possibilities

The proposed project for implementing a fish hatchery for grayling in the Municipality of Bosanska Krupa could be seen as a sustainable development pilot project. If it proves successful, it could be implemented in other municipalities, not only in the Una-Sana Canton region, but across Bosnia. The proposed fish hatchery itself could be expanded in the future to fulfil the needs of stakeholders in the Municipality. Examples of expansion could include production of fish-species such as Danube salmon (*Hucho hucho*), brown trout (*Salmo trutta m. fario*) and others.

2.6 Therapeutic Value of the River

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 years of shelling and shooting. According to Sertovic M., some of the citizens have expressed that walks near river, with or without fishing rods, are beneficial to their psychological health (Sertovic, M. 1997, pers. comm.).

2.7 Fish as Commodity in the Marketplace

The proposed fish hatchery, besides raising fry for the stocking of waterways, could raise fish for the marketplace and restaurants. Fish is a valuable commodity both at the marketplace and in restaurants. Furthermore, fishing organizations from other municipalities could purchase fry for the purpose of stocking their own waterways.

2.8 Visits by Domestic and Foreign Anglers

Having a local fish hatchery is likely to increase the number of fish in the waterways of Bosanska Krupa, as long as the primary role of the fish hatchery is to stock the waterways with fry. The increase of fish in the waterways of Bosanska Krupa will naturally attract greater number of fishermen from Bosanska Krupa and beyond. Before the war, foreign anglers from Italy, Austria, the Netherlands, Germany and other parts of Western Europe came to the rivers of Bosanska Krupa to fish. Their visits positively contributed to the economy of the municipality. As the fish population improves with a successful introduction of fry from the proposed fish hatchery, foreign and domestic anglers are likely to return to these waterways in larger numbers. This will financially benefit the Organization for Sport Fishermen (OSF) as they receive more money from issuing a greater number of fishing licenses.

2.9 Eco-Tourism on the River Krusnica beyond Fishing

There used to be a twenty-passenger boat that operated for tourists and visitors from where the River Krusnica joins the River Una, all the way to the source of the River Krusnica. The boat used to stop about 250 meters from the source of the River Krusnica. Dutch tourists represented the majority of international guests who used to travel by boat to the source of the River Krusnica (Sertovic A. 1997, pers. comm.). There is a camping spot near the source and visitors and tourists used to barbecue there. At the source of the river is a mysterious cave that is narrow and hard to get into. However, 500 meters down-river from the source of the River Krusnica on the right side (west) is another cave that is much larger and more accessible. A person could walk for almost a kilometer in this cave. The cave is famous for beautiful stalactite and stalagmite formations. There are numerous caves in the mountains of Grmec and many of them provide habitat for the alpine newt (*Proteus anguinus*) (Solaja and Pocrnjic, 1991). In addition, populations of Proteus only exist in isolated systems of underground water of Dinaric karst, particularly

a system in Grmec mountain. Today these regions are parts of Bosnia and Herzegovina, Croatia, Slovenia and Italy. The geological basis of the cave canals are chalk-limes with a large percentage of calcium carbonate ($CaCO_3$) (Davidovic, 1977).

2.10 Kayaking and Canoeing

The River Una and its tributaries, including the River Krusnica, have ideal waters for kayaking and canoeing. Before the war, numerous white-water enthusiasts used to come to these waters in search of adventure and natural beauty. Since the end of the war, starting in the summer of 1996, an international kayaking competition has been hosted by the city of Bihac. The length of the race is 50 km, starting in the town of Martin Brod, through the city of Bihac, to the town of Bosanska Krupa (Tehnicka Jedinica, 1997). Kayaking and canoeing are eco-tourism activities that can coexist with successfully implemented fisheries management. Those who kayak or canoe may also want to fish, which means that they will need to buy a fishing permit, in turn helping local fisheries management and the municipal economy.

2.11 Hunting

In the Municipality of Bosanska Krupa, there is a hunting organization called "Divojarac" (mountain goat) (Sehic 1997, pers. comm.). Wildlife resources are managed by hunting organizations in Bosnia, similar to the way fish are managed in continental waterways by OSF. Many hunters are also anglers, and as such, they may also buy fishing permits. A successful coordination between the hunting organization and the OSF would create mutual financial benefits for both. This maybe especially important for those foreign enthusiasts who come for this kind of activity with lots of money. Birds and animals that live in the forests of the municipality of Bosanska Krupa which are hunted for food, fur and trophy include: wild duck (*Anas platyrhynchs*), eagle (*Aguila shrysaetus*), wild pigeon (*Columba palumbus*), forest owl (*Bubo bubo*), grouse (*Tetrao urogallus*), wild rabbit (*Lepus europaeus*), golden marten (*Martes martes*), big weasel (*Mustela erminea*), brown bear (*Ursus arctos*), gray wolf (*Canis lupus*), red fox (*Vulpes vulpes*), wild cat (*Felis silvestris*), deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) (Ritz, 1973; Mogus, *et. al.*, 1981; Lovacko Drustvo "Grmec", 1990). A more complete list of wild birds and animals that are harvested by hunters is presented in Appendix C.

2.12 Land Mines

According to the United Nations Mine Action Centre (MAC), there are 1417 known land mine fields in the Una-Sana Canton and most of these fields are in the Municipality of Bosanska Krupa. It is estimated that over 10,000 land mines and other explosive mechanisms exist in the Municipality of Bosanska Krupa alone. The River Una played an important role in separating the Serbian positions with those of the Bosnian forces. Many shorelines of the River Una and other watersheds are mined. Today this creates a problem for fishermen who use the shorelines for fishing. The following statistics from MAC record known mine incidents that occurred in the Una-Sana Canton between January 1, 1996 and August 31, 1997.

Table 2-A Land Mine Incidents in the Una-Sana Canton

Killed	13
Serious Injury	26
Minor Injury	16

(MAC, 1997)

According to the land mine experts in the MAC and the Civil Defense Department of Bosanska Krupa, the shores of the River Krusnica are now free of land mines; therefore it is more attractive for fishing and eco-tourism than any other waterway in the municipality (Civilna Zastita 1997, pers. comm.). They had been cleared (100%) in the summer of 1997 from the land mine field on the left bank of the River Krusnica (500 meters before it converges with the River Una) (Civilna Zastita 1997, pers. comm.). In Figure 2.1, wooden posts indicate the locations of land mines that have been cleared on the banks of the River Krusnica.

Figure 2.1 Location of Cleared Land Mines on Left Bank of the River Krusnica

CHAPTER 3: METHODOLOGY

3.1 Literature Review

The literature review assisted me in gaining insight and knowledge on topics related to the overall objectives of the MDP. It helped me better define the research purpose, develop insightful questions, identify contacts and link the study with previous research (Yin, 1989). The literature review and its findings gave me the flexibility to incorporate new and focused issues in the MDP which were ignored in earlier phases of planning.

The literature review was conducted in both the Bosnian-Croatian-Serbian and English languages. The review was conducted in libraries both in Bosnia and Herzegovina and in Canada. It included the following topics: sustainable development, war in Bosnia and Herzegovina, aquaculture, grayling (*Thymallus thymallus*) and fisheries management. It was conducted using sources such as CD ROMs, DOBIS on-line, key word searches, government and non-government reports, policy statements, previous MDPs, books and journals that were relevant to the topic. Information was also gathered from the Bosnian government, municipal government, domestic and foreign non-government organizations, conservation organizations, United Nations organizations, the World Bank and other aid organizations that operate in Bosnia.

A literature review was also carried out in the area of social research methodologies. Such research aided in development of research instruments (i.e. criteria for selecting key informants and guidelines for interview). It also identified ways of assessing and analyzing qualitative data. Furthermore, the literature review of social research methodology assisted in the development of guidelines for reporting research findings. Finally, the literature review in this area identified how to perform key informant interviews. Special attention was given to identifying cultural and language differences in social research methodologies in order to minimize information errors.

Social science research methodology references such as Kumar (1989), Neuman (1994), Pratt and Loizos (1992) and Robson (1993) were extremely useful sources.

3.2 Key Informant Interviews

Key informants are those individuals who are knowledgeable about some aspect of the researcher's study and are willing to assist in research (Pratt and Loizos, 1992). Information that is achieved from the interview is generally qualitative in nature (Kumar, 1989). Key informants were extremely important to the project because gathering information through secondary means is limited in Bosnia.

Key informant interviews were used to gain insight and knowledge on topics related to the overall objectives of the MDP. The interviews were conducted in either Bosnian-Croatian-Serbian or English, depending on the informant's preference, and were focused on the regional context. Key informant interviews were well suited for this research because of the lack of written regional data. Key informants included Bosnian government officials, scientists and technical experts, domestic and foreign non-governmental agency representatives, members of angling organizations, fisheries management experts, fish hatchery employees, MDC members, TU members, war invalids, foreign financial donor employers, members of conservation organizations, planners and academics with special interest in sustainable development in Bosnia. Approval from the University of Calgary ethics committee was obtained before proceeding with key informant interviews.

Four criteria for selecting key informants were used from Tremblay (1982):

Role – The key informants have a role in meeting the project's objectives. For this project, these individuals were Bosnian government officials, scientific and technical experts, domestic and foreign non-governmental agency representatives, members of angling organizations, fisheries management experts, fish hatchery employees, MDC members, TU members, war invalids, foreign financial donor employers, members of

conservation organizations, planners, and academics with special interest in sustainable development in Bosnia.

Knowledgeability – The key informants have knowledge about a topic of the project.

Willingness – The key informants were willing to provide the information that is relevant to the MDP research and willing to cooperate with researcher.

Impartiality – The key informants minimized their personal biases related to the research. If they could not minimize their personal biases, they let me know about them (Tremblay, 1982).

Key informant interviews were conducted in informal settings, and were recorded in a hard-covered notebook. Interviews took place in numerous locations and settings including: offices, while driving, over a meal, site visiting, over a drink, or while visiting their homes. Some of the key informant interviews lasted over two hours, while others lasted for about ten minutes. Some key informants provided information to this MDP numerous times over the period of one year, whereas others contributed only on one occasion during the research. There were more than a dozen key informants participating in this research, the majority of them in Bosnia. Their names and affiliations are listed in the Key Informants and Personal Communication section of this project.

Key informants were asked a general question in a specific area that pertains to the research. After a general question was asked, they would be asked to provide more detailed answers to parts of the questions and suggest options. In the area that directly pertains to fisheries management, for example, key informants were asked two basic questions:

1. What caused the fish population decline in the waterways of the Municipality of Bosanska Krupa?

2. How can the problem be solved?

3.3 Analysis of Data

Most of the data, especially from non-scientific key informants, is qualitative and is treated as such. I was trying to get as much data as I could on the environmental and natural resources of the municipality. Reflections that occurred to me during processing of the data were also incorporated into the notebook, but these reflections were differentiated from the data itself. Techniques suggested by Robson, including prolonged involvement, persistent observation, triangulation and peer debriefing were used in data analysis (Robson, 1993).

3.3.1 Prolonged Involvement

The six months that I spent in northwestern Bosnia allowed me sufficient time to build trust and test for misinformation. Being a native of Bosnia, fitting into the native culture was natural. Prolonged involvement allowed me to go through repetitive procedures that were essential in the research (Robson, 1993).

3.3.2 Native and Educational Background

Being a native of Bosnia has helped me tremendously in acquiring the necessary information for the project. Communication with the local people was easier for me than for other researchers who do not understand the language. Communication was easy and the willingness of the local people to share information was enhanced when they understood who I was and what the information would be used for. Besides my educational background in environmental science, angling (something that I have been doing since the age of four) has added to the enthusiasm of this research topic.

3.3.3 Site Visit

The internship with the UNOPS office in Bihac allowed me to visit the Municipality of Bosanska Krupa many times during my six-month stay there. On average I visited the municipality twice a week. Close to the end of my internship, I spent ten consecutive days staying in the home of Mr. Fikret Harbas, who works in the TU of the municipality. I made site visits to all of the places discussed in this project. Site visits to the River Krusnica and the River Una were numerous and were carried out periodically throughout the six-months. Activities on both rivers included walking, angling, boating and swimming.

3.3.4 Persistent Observation

Observations were being carried out throughout my stay in Bosanska Krupa. The objectives of the project and its goals were considered while making the observations. Strategies recommended by Robson, such as space, actors, activities, objectives, acts, events, time and goals were used as in the observation component of methodology (Robson, 1993). These observations were recorded in the hard-covered notebook. Photographs were taken during my stay in the Municipality, some of which are included in this document.

3.3.5 Triangulation

Data and information, whenever possible, were checked against other sources of information. Information from literature review was checked against information from key informants and vice versa. Furthermore, information from one key informant was checked against that from another. Literature review articles on the same subject were also checked against one another. All of these triangulation techniques were used to enhance credibility of data and information (Robson, 1993).

3.3.6 Peer Debriefing

Peer debriefing was done on a continuous basis during my stay in Bosnia with Mr. Bosko Marjanovic who is an environmentalist, and past president of the largest environmental NGO in northwestern Bosnia called "Unski smaragdi". I shared data and information with him that I had collected, and I also discussed my thoughts and observations with him. This activity assisted me in both the data analysis and case study design aspects of the research and enhanced the credibility of both.

3.4 Limitations of Research

The Serbian Army occupied the center of Bosanska Krupa from April 1992 to September 1995. The Municipality building was located in the center of town and was home to numerous documents including those in the areas of environmental science that were relevant to the MDP. The municipality building was burned prior to September 1995, when the Bosnian Army gained control of Bosanska Krupa, and much of the information was destroyed by fire. Some of the information was stolen and some deteriorated because of rain and other adverse weather conditions. Both the quality and quantity of the municipal data were lacking in all areas, especially in the area of environmental science. This was one of the main limitations of the research.

As discussed earlier, the objectives of the MDP research were adjusted upon my return to Calgary. Further follow-up to key informant interviews with persons in Bosnia could not be done in many cases. An e-mail system does not exist in the Municipality of Bosanska Krupa and telecommunication lines are not reliable. Communication through the contact person(s) in the UNOPS office in Bihac was carried out with some key informants in the municipality. Some follow-up information was obtained through the e-mail and fax communication that was done through the UNOPS office in Bihac.

The ability to spend six months doing fieldwork provided me with valuable information. I was able to get excellent information from key informants, site visits and observations.

Once back in Calgary, I was able to obtain a vast amount of information through a literature review on the overall subject of my research – something that was greatly lacking in Bosnia. The Municipality of Bosanska Krupa has a town library which was damaged during the war (12%), but its book collection is extremely poor (University of Sarajevo – Faculty Institute of Economics, 1997). The City of Bihac (56,863 people) has only one public library with very few books, and none that were directly related to the MDP topic. Unfortunately, this is the reality for many places in the world, especially those that depend on international aid from other countries and international organizations.

CHAPTER 4: PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF THE RIVER KRUSNICA

The last study on fishing for the waters of the Una basin (this includes the River Una and its tributaries) was carried out in 1984 by the Institute for Biology at the University of Sarajevo. No other fishing base studies have been conducted in the last fourteen years (Harbas H. 1997, pers. comm.). A limitation of the study is that the methodology is not available in text form. I was not able to obtain the information on how certain calculations were produced by directly contacting the Institute for Biology at the University of Sarajevo. I reviewed data in the study together with Dr. Thomas Hamor, fish biologist at Sam Livingston Fish Hatchery (Calgary, Alberta), and the study seems to be scientifically sound and valid (Hamor 1998, pers. comm.).

Even though outdated, this is the best study available on the River Una and the River Krusnica. Today, it is estimated that the fish population in the River Krusnica is only 10% of what it use to be before the war (Harbas H. 1997, pers. comm.). Since OSF (the organization that paid for the last study) presently does not have adequate financial resources available, it is unlikely that they will be hiring a consultant in the near future to do a fisheries assessment in the municipal waterways. Furthermore, technical expertise in this field of work is lacking in Bosnia because many of the qualified people have left the country.

4.1 Basic Hydrographic and Geologic Characteristics

The River Krusnica is the right tributary of the River Una. The River Krusnica flows into the River Una near the center of the city of Basanska Krupa. The entire length of the River Krusnica is within the municipal boundaries of Bosanska Krupa (Figure 5.1). The length of the river is 6.8 km. It emerges from a cave as a collection of underground streams collected throughout the Mountain Grmec and the neighboring hills. Stability of flow is relatively constant throughout the year and therefore there is no great difference in water flow between early spring and late summer. Constant stability of water flow is an

extremely important condition of any successful flow-through aquaculture facility. Limestone is present throughout the riverbed, colored between white and gray. Formed by inorganic precipitation of carbonates, clay minerals and/or silica (as quartz grains, chalcedony, and chert) are present in considerable proportions in most limestone (Strahler, 1981).

One of the important hydrographic characteristics of the River Krusnica is that it continuously receives water from groundwater springs and is a large stream before merging into the River Una. The width of the River Krusnica is about 15 m in the upper reaches. In the lower reaches it is about 30 m wide (Military Survey, 1996). Most of the river's depth varies between 50 cm and 1 m, with the deepest points about 2 m.

The elevation at the source of the River Krusnica is 200 m and the elevation where the River Krusnica joins the River Una is 140 m (Defense Mapping Agency, 1994). This makes the difference in elevation 60 m over the length of the River Krusnica (6.8 km) (Institute for Biology at the University of Sarajevo, 1984).

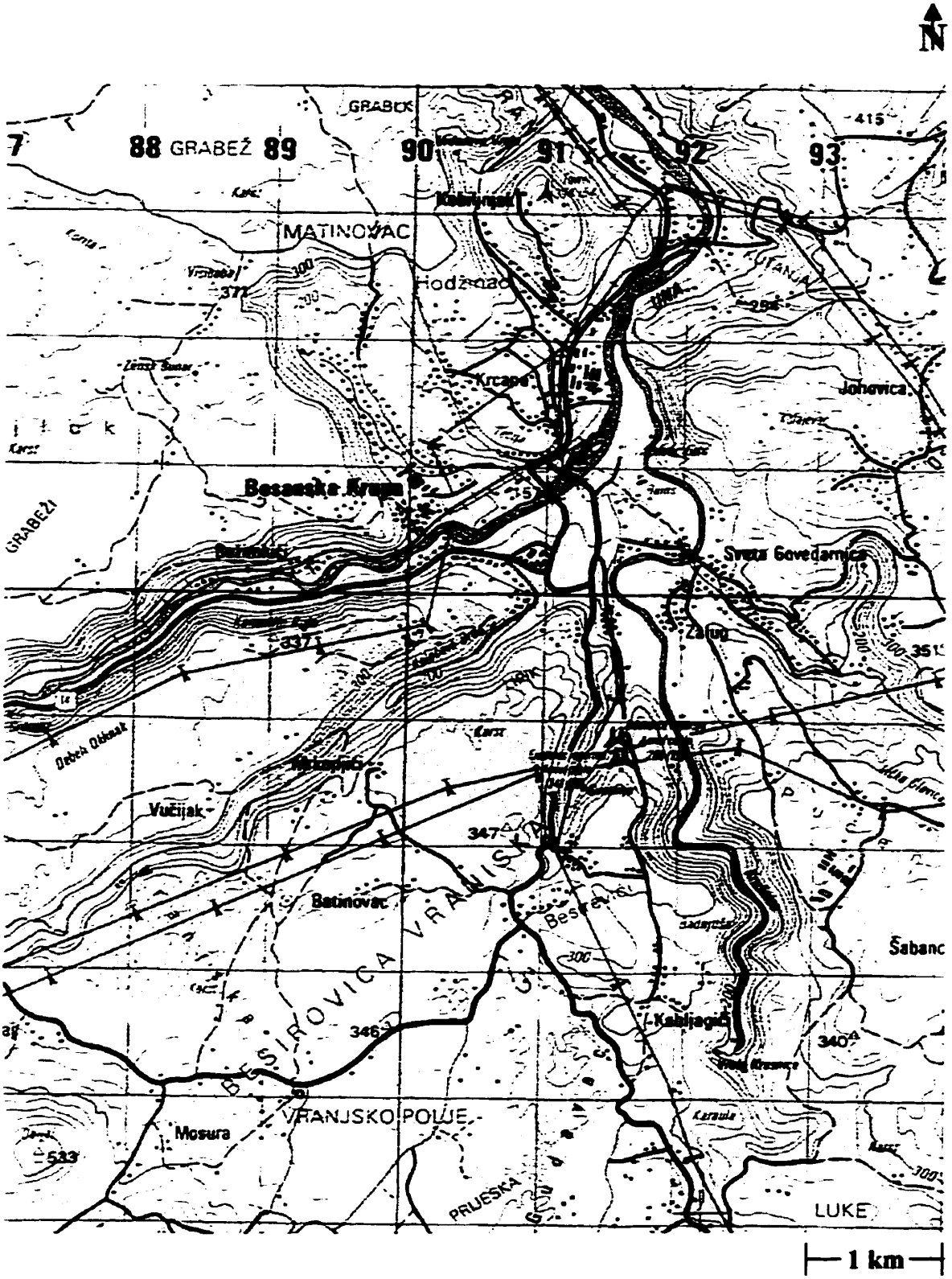


Figure 4.1 The River Krusnica and its Receiving River (the River Una) (Defense Mapping Agency, 1996).

Figure 4.2 Source of the River Krusnica (Saric 1997, pers. comm.).

Figure 4.3 Lower Reach of the River Krusnica (Saric 1997, pers. comm.).

The two main characteristics of the Krusnica's flow are its short length and the karst terrain. Stability of flow is one hydrographic characteristic of karst. This characteristic provides a stable aquatic environment for all aquatic organisms (both plant and animal) throughout the year. In other words, in this type of environment, there is lots of food for fish throughout the year. Another characteristic of karst is relatively constant water temperature. Just like stable water flow where risk of flooding is not great, constant water temperature is also very important in a successful flow-through aquaculture facility. Another characteristic of karst is that there is very little siltation. This is another positive aspect not only for the fish in the river, but also in the aquaculture facility itself. The physical and biological characteristics of the River Krusnica are very similar to those of the River Test in the United Kingdom, considered to be one of the best trout streams in the world. In the upper parts of the River Krusnica, the banks of the river are relatively high and steep. Another hydrographic characteristic of karst is alkalinity. High alkalinity means a good buffering capacity. The stream, its surroundings and the organisms that depend on it are less susceptible to the detrimental effects of acid rain. In the lower reaches, the banks of the river are very low and flat. The water of the River Krusnica is extremely clear and clean. Many of the local people in Bosanska Krupa drink the water straight from the River Krusnica, even in its lower reaches.

4.2 Ecological Differentiation of the River Una System

The River Una ecological system is very special and the River Krusnica is part of it. The canyons and the valleys of the River Una system are part of the northwestern Dinarids that host a range of ecosystems from submediterranean to alpine (Lakusic, et. al., 1991).

Various types of vegetation are present in the valleys of the River Una system. Vegetation inventories revealed more than 177 species of officially-recognized medicinal plants and about 105 vitamin-rich, edible and potentially medicinal plants (Redzic et. al., 1991).

The habitat found in and around the River Krusnica is a classic riparian zone. Beside a numerous species of fish, the River Krusnica is home to salamanders (*Salamandra salamandra*), tortoises (*Emys orbicularis*), otters (*Lutra lutra*), wild ducks (*Anas platyrhynchos*) and garter snakes (*Natrix tessellata*), among others. Most of the animals that are hunted (see Appendix C) also use the riparian zone of the river.

4.3 Chemical and Physical Properties of the Water

All the indicators obtained by analytical testing show that the water of the River Krusnica is extremely suitable for fish (Institute for Biology at the University of Sarajevo, 1984). Its water provides very good habitat for salmonids in the upper reaches of the river because the gradient is steep and rapids are numerous. In the lower reaches, the gradient is lower and the habitat is excellent for cyprinids (*Cyprinidae*). The temperature of the water on October 10, 1984 was 10.4 °C and alkalinity was 7.9 mval (Hygienic Institute in Bihac, 1984). Dissolved oxygen is exceptionally high, measured at 9.4 mg/L (Institute for Biology at the University of Sarajevo, 1984), further increasing suitability for fish. In water quality analysis in laboratories, no organic or other pollutants were found (Hygienic Institute in Bihac, 1984). A summary of the physical characteristics of the River Krusnica is provided in Table 4-A. It is concluded that the quality of the water of this river is very good (Hygienic Institute in Bihac, 1984).

Table 4-A Water Survey of the River Krusnica Near Pepine Luke

Date of water sampling	October 10, 1984
Color	Without color
Smell	Without smell
Temperature of the water	10.4 °C
pH	7.1
Alkalinity	7.90 mval
Total hardness	8.45 °nj
Dissolved oxygen	9.4 mg/L

(Hygienic Institute in Bihac, 1984).

4.4 Biological Characteristics of the River Krusnica

Samples for analysis of zoobenthos were taken twice at the bottom of the River Krusnica at the same location, near Pepine Luke (Institute for Biology at the University of Sarajevo). Pepine Luke is located 3 – 4 km from the source of the River Krusnica (Pasalic 1998, pers. comm.). This was done so more precise data could be obtained to determine the quantity and the type of organisms that live at the bottom of the river. Without good knowledge of the river bottom, it is impossible to obtain good parameters for evaluation of settlements (in terms of location and quantity) for different species of fish, nor establish principles to manage the river basin. Results that were obtained from analyzing the collected samples are presented in Table 4-B and are summarized in the following paragraph.

In the River Krusnica, there are seven groups of living organisms whose numbers differ. The most common are *Mollusca* (molluscs, e.g. snails and mussels) with 30.45% representation, followed by *Ephemeroptera* (mayflies) with 16.66% and Dyptera (flies and mosquitoes) with 15.94%. It is important to recognize that molluscs (*Mollusca*) perform processes that clean the water in a river. There are no fears of inorganic pollution because the indicators of water quality, during the testing, show very high

ecological integrity. The high number of zoobenthos per unit of area (929/cm^2) indicated a large abundance of prey for fish in the River Krusnica.

Table 4-B Quantity-Quality Analysis of Zoobenthos in the River Krusnica

System Category	Number	%
***Mullusca* (molluscs) e.g. snails and mussels**		
- *Theodoxus sp.*	14	10.17
- *Amphimelania sp.*	12	8.69
- *Fagotia*	11	7.97
- Unidentified	5	3.62
***Amphipoda* (crustaceans) e.g. shrimp**		
- *Gmmaridae*	33	23.91
***Ephemeroptera* (mayflies)**		
- *Baetidae*	20	14.49
- *Ephemerlla*	3	2.17
***Dyptera* (flies and mosquitoes)**		
- *Chironomidae*	20	14.49
- *Limoniidae*	4	1.45
Trichoptera species	9	6.52
***Coleoptera* (beetles)**		
- Elmis	5	3.62
- Noterus	2	1.45
***Oligochaeta* (worms with few bristles)**	2	1.45
Total	138	100%

(Institute for Biology at the University of Sarajevo, 1984)

The average amount of biomass in the River Krusnica was 530 kg per ha, and the total amount of biomass is 7420 kg (Institute for Biology at the University of Sarajevo, 1984). The average biomass was calculated using different locations on the river, not just near Pepine Luke (Institute for Biology at the University of Sarajevo, 1984). According to the Institute, the biomass in the River Krusnica can sustain a fish population from 1855 kg to 3710 kg (Institute for Biology at the University of Sarajevo, 1984). The present fish population in the River Krusnica indicates that stocking of fish-fry is needed in order to bring the population up to the levels which can be sustained by the high biological production of the River Krusnica (Institute for Biology at the University of Sarajevo, 1984). In 1984, the population of fish in the river was much lower than could be sustained naturally, because of high angling pressure (Institute for Biology at the University of Sarajevo, 1984).

4.5 Status of the Fish Population According to Species

The range of fish species in the River Krusnica varies from the source to the mouth of the river. However, grayling (*Thymallus thymallus*), which represents 23% of the overall fish population in the river, is the most common species (Institute for Biology at the University of Sarajevo, 1984). Danube roach (*Rutilus pigus virgo*) represents 20%, followed by nase *(Chondrostoma nasus*) with 18%, brown trout (*Salmo trutta m. fario*) with 11% and so on (see Table 4-C). In the River Krusnica, there are eight registered species of fish that have economic value on the marketplace. In 1984, it was estimated that this stock of fish species was 1229 kg, which was estimated to be 17,248 fish (Institute for Biology at the University of Sarajevo, 1984). The average population density was estimated at 88 kg/ha (Institute for Biology at the University of Sarajevo, 1984). Salomonids were the most common in the higher parts of the river, whereas cyprinids were the most common in the lower reaches (Institute for Biology at the University of Sarajevo, 1984).

Table 4-C Fish Species in the River Krusnica **P = 14 ha**
88 kg/ha

Species of Fish	%	Basic stock in kg	Basic stock in number of fish
Brown Trout (*Salmo trutta m. fario*)	11	136	1904
Danube Salmon; Huchen (*Hucho hucho*)	4	53	159
European Grayling (*Thymallus thymallus*)	23	286	3432
Nase; Common Nase (*Chondrostoma nasus*)	18	224	3136
Chub; Skelly; Graining (*Leuciscus cephalus*)	6	70	1050
Barbel (*Barbus barbus*)	7	103	1442
Danube Roach (*Rutilus pigus virgo*)	20	244	3660
Pike; Jack, Northern Pike (*Esox lucius*)	5	61	305
Other species	6	72	2160
Total	100	1229	17,248

(Institute for Biology at the University of Sarajevo, 1984)

4.6 Dynamics of Fish Population Growth and the Estimates of Fishing Trips at the River Krusnica

According to the analysis that was carried out in regard to the population of zoobenthos, a food source for fish, it is estimated that the natural characteristics of the River Krusnica can sustain over 270 kg of fish per hectare (Institute for Biology at the University of Sarajevo, 1984). In 1984, the density was measured at 88 kg/ha (Institute for Biology at

the University of Sarajevo, 1984). Intensive stocking, one of the recommendations in the study, is to be carried out in successive years to bring the fish population to appropriate levels. Populations of fish do not increase because of very high angling pressure at the River Krusnica (Institute for Biology at the University of Sarajevo, 1984). Therefore, the Institute recommended that stocking be done.

The following management chart (Table 4-D), shows that the fish population density was projected to improve. In 1985, fish population density was projected to be 106 kg/ha, in 1989 it was projected to be 115 kg/ha, and in 1993 it was projected to be 227 kg/ha.

The number of fishing visits to the River Krusnica increased each year before the war (Harbas H. 1997, pers. comm.). Expected fishing visits are indicated in Table 4-D. The Institute pointed out that visits must be in the category of sport-fishing and all those who come to fish need to abide by fishing laws governing the type, size and quantity caught, as well as catching methods (Institute for Biology at the University of Sarajevo, 1984). Table 4-D indicates that in 1984, 860 daily fishing visits were projected and in 1993 the projection was 2028 daily visits (Institute for Biology at the University of Sarajevo, 1984).

From Table 4-D, we can see that stocking with brown trout (*Salmo trutta m. fario*) and grayling (*Thymallus thymallus*) was recommended by the Institute for both species (three times) over ten years (Institute for Biology at the University of Sarajevo, 1984). Stocking of the River Krusnica with brown trout was going to happen in 1984, 1987, and in 1990. Each time, the River Krusnica was supposed to receive 5000 fry of brown trout. Similarly, stocking of the River Krusnica with grayling was supposed to happen three times in 1985, 1989 and 1992, each time with 5000 fry of grayling (Institute for Biology at the University of Sarajevo, 1984). Laws concerning acceptance of fry and their release into the River Krusnica by the representatives of the OSF of Bosanska Krupa had to be respected entirely. With this dynamic of stocking, increase in fish population at the end of anticipated period was expected to be 1980 kg of sexually mature brown trout and grayling. These results can only be expected if there was no future pollution of the water.

Table 4-D Projected Number of Fish Taking into Account the Implementation of Stocking

Year	Basic stock in kg	Stocking with fish fry	Natural growth	Artificial growth	Permissible catch	Total basic stock	No. of daily fish-outings
1984	1229	5000 brown trout fry	409.66	-	286.76	1351.90	860
1985	1351.90	5000 grayling fry	450.63	-	315.44	1487.09	946
1986	1487.09	-	495.69	-	346.98	1635.80	1040
1987	1635.80	5000 brown trout fry	545.26	125	381.68	1799.38	1450
1988	1799.38	-	599.79	125	419.85	1979.32	1255
1989	1979.32	5000 grayling fry	659.77	-	461.84	2177.25	1385
1990	2177.25	5000 brown trout fry	725.75	125	508.02	2394.98	1524
1991	2394.98	-	798.32	125	558.82	2634.48	1676
1992	2634.48	5000 grayling fry	878.16	-	614.71	2897.93	1844
1993	2.897.93	-	965.97	125	676.18	3187.72	2028

(Institute for Biology at the University of Sarajevo, 1984)

Recommended stocking procedure was not carried out during the years of 1992 and 1993 because of the war. From 1984 to 1991, only partial stocking was carried out at the River Krusnica (Harbas H. 1997, pers. comm.). The angling pressures remained high, even before the war, and projections made in the 1984 study by the Institute were not achieved (Harbas, H. 1997, pers. comm.).

CHAPTER 5: SITE ANALYSIS

5.1 Close Proximity to the Existing Micro Hydroelectric Powerplant

The proposed aquaculture operation on the River Krusnica is advised on the left bank (west), about 200 m from the source of the river. Also on the left bank is a micro hydroelectric powerplant about 100 m from the source of the river. The hydroelectric powerplant is a small unit built in 1947 (Harbas, F. 1997, pers. comm.). Turbines use free-falling water (about 1.71 MW of energy) to generate approximately 7.5 GWh of electricity (Ekonomski Fakultet Univerziteta u Sarajevu - Institut, 1996). This power is used to supply the municipal electrical grid and is mostly consumed by households in the nearby villages. The close proximity of the micro hydroelectric power plant does not have any negative effects on the water quality, nor does it alter the water in any way (e.g. thermal change and flow rate). This hydroelectric powerplant would not have an adverse impact on the proposed aquaculture. The advantage of having the powerplant in close proximity to the proposed aquaculture facility is that electricity can be provided for certain activities in the aquaculture (i.e. use of electrical appliances such as radio, telephone and refrigerator by the staff and to serve lighting, heating and cooking needs).

5.2 Accessibility to Road

The proposed aquaculture location, explained in the above paragraph, is 300 m from the closest road in the municipality (Harbas, F. 1997, pers. comm.). A road for vehicle use cannot be easily built to the river because of terrain steepness from the nearest existing road to the proposed aquaculture facility. However, the proposed aquaculture does not need immediate vehicle access. A pedestrian walkway is already in place, commonly used by citizens of the municipality who want to go to the source of the River Krusnica. Those who are involved in the operation of the micro hydroelectric powerplant also use the walkway. For the purposes of the proposed aquaculture operation, the already existing road (300 m away) and pedestrian pathway (connecting road with the proposed location) are adequate.

5.3 Motel

A motel that used to operate before the war is in close proximity to the proposed aquaculture site and micro hydroelectric powerplant. The motel had five rooms and could accommodate 15 guests (Redzic 1997, pers. comm.). It used to employ up to six people during the peak season (summer months). The employees included a manager, cooks, waiters and cleaners. The motel was used by local and foreign tourists who sought for isolated and natural locations that offered peace and quietness. It was also frequently used by anglers. From there, they had excellent fishing access to the River Krusnica. During the war, it was vandalized by the Serb Army (Harbas, F. 1997, pers. comm.). Renovations to the building could be achieved with little work and financial input. If renovated, the motel could continue operating as it did before the war, providing accommodation to fishing enthusiasts and those who enjoy the remote natural environment. The motel may also serve as a meeting venue for different events (i.e. environmental education and stakeholder meetings for fisheries management and aquaculture). Meetings for the OSF could be held at the motel, especially because the organization does not have its own meeting space.

5.4 Village of Kabljagici

The village of Kabljagici consists of about 28 houses (Defense Mapping Agency, 1996). It is the closest village to the proposed aquaculture facility, approximately 500 m away. If the proposed project is built and becomes operational, this village would see much more frequent traffic. Parking space is also an issue that needs to be considered.

CHAPTER 6: PRESENT FISHERIES MANAGEMENT ON THE RIVER UNA AND ITS TRIBUTARIES

The management of fish populations in all waterways of the Una basin is done by the Organization for Sport Fishermen (OSF) of individual municipalities. An OSF manages all aspects of fishing activity. Harvesting of the fish population is exclusively done in terms of sport fishing, i.e. solely with the use of a fishing rod. Exploitation of fish in any other way, i.e. the use of fishing nets, electric current, fish traps and explosives, is prohibited.

6.1 The Role of Organization for Sport Fishermen

The Organization for Sport Fishermen (OSF) of Bosanska Krupa is the sole organization overseeing every aspect of fishing activities in all bodies of water that are within the borders of the municipality of Bosanska Krupa. It is important to mention that OSF is a volunteer organization. The organization is knowledgeable about the fish species that are present in the municipal waterways. It keeps records of the number of their members and the number of fishing permits they issue for particular periods of time. The organization is also responsible for keeping track of the norms of the catch (daily fishing visits and the number of fish that are caught) and it oversees the implementation of part-time and full-time bans on fishing at certain localities. The OSF monitors and protects the natural spawning locations for fish. It carries out the stocking of fry into the bodies of water. The organization determines fees for fishing licenses and employs the Fisheries Enforcement Officers (FEO) who check fishing licenses and examine the number of fish caught and their size. It monitors the quality of water and is responsible to report pollution levels that are higher than normal, especially if they endanger the fish population (Selimovic, 1991).

6.2 Finances of the OSF

In order to have successful fisheries management, there needs to be a well-managed financial mechanism. The OSF must have a balanced budget or make some profit in order to carry out its tasks from one year to the next. Past revenues and expenses for the OSF of the Municipality of Bosanska Krupa were divided in the following ways:

Revenues

- Yearly fishing licenses for adults
- Yearly fishing licenses for students
- Daily fishing permits
- Compensation (indemnity) from poaching
- Compensation (indemnity) from polluters
- Grants from local organizations
- Leftover funds from previous year

(Institute for Biology at the University of Sarajevo, 1984).

Expenses

- Yearly salary for FEOs
- Stocking of waterways
- Membership fee to the association of the Republic's OSF
- Travel expenses
- Administration
- Advertisement of regulations
- Postal Office costs
- Communication costs (telephone, fax)
- Meetings and seminars
- Costs associated with renting space for meetings

(Institute for Biology at the University of Sarajevo, 1984).

6.3 Number of Anglers

In 1998, there were 398 registered anglers in the Municipality of Bosanska (Harbas F., 1998, pers. comm.). This number is lower than that of registered anglers before the war, 512 members (Selimovic, 1991). The percentage of anglers per overall population of the municipality has increased; the population of the Municipality of Bosanska Krupa was 58,212 before the war and it is presently 27,336 (Harbas, F. 1997, pers. comm.). The percentage of those who regularly fish has increased from 0.88 % before the war to 1.46% after the war. This is a good indicator suggesting that because of grim economic prospects, more people have turned to fishing to include fish in their diets. According to Harbas F., there are about 60 regular poachers fishing the waterways in the municipality (Harbas, F. 1998, pers. comm.). The number of poachers has increased dramatically since 1991, placing further pressure on already-strained fisheries resources in the municipality (Harbas, F. 1997, pers. comm.).

6.4 Annual Fishing Licenses

The 1998 annual fishing license for an adult costs 70 DM (~$60 CDN) (Harbas F. 1998, pers. comm.). This has gone up by 30 DM (almost double), since the previous year when the annual fishing license for adults was 40 DM (Harbas F. 1997, pers. comm.). This drastic increase in the price of annual fishing licenses probably reflects the OSF's realization that fishing resources have been greatly depleted. The price increase may also be aimed at reducing the number of anglers in the municipality. The annual fishing license for students is 35 DM (~$30 CDN). The daily fishing license for foreigners is 10 DM (~$8 CDN) (Harbas F. 1998, pers. comm.).

6.5 Fisheries Enforcement Officers (FEOs)

The OSF organizes and manages Fisheries Enforcement Officers (FEOs). Some FEOs work throughout the year and some work only seasonally. In 1990, there were two FEOs in the Municipality of Bosanska Krupa (Selimovic, 1991). It is recommended that there be three times more officers in order to successfully monitor the area (Selimovic, 1991).

The FEOs play an important role of monitoring all fishing activities on waterways. This monitoring is an extremely important component of fish-resource protection and fisheries management. In order to have successful fisheries management in place, so projections can be made (i.e. fish growth, fish-catch, and daily fish-outings), it is important to monitor those who fish legally and illegally. This aspect of monitoring is extremely important especially because the number of anglers has been growing steadily. Growth of fishing pressure has occurred in all of the three time periods: before the war, during the war and after the war (Harbas H. 1997, pers. comm.).

Besides monitoring fishing activities on waterways, FEOs are involved with numerous other activities that are related to:

- Protection of natural spawning grounds during the spawning season
- Monitoring pollutants in the waterways
- Guarding against the exploitation of mineral resources (i.e. extraction of lime-stone, sand, rock and gravel)
- Extermination of pests
- Other activities that relate to fisheries management
  (Institute for Biology at the University of Sarajevo, 1984).

6.6 Sustainability of Fisheries Resources

In each waterway, fish have their own carrying capacity where a given body of water cannot sustain more fish than what are permitted by their own biological characteristics. This ecological rule was used as the basis for passing a fisheries management law (Sl. list SR BiH 35/79) where a maximum yearly catch allowed cannot exceed the yearly reproduction capabilities (Institute for Biology at the University of Sarajevo, 1984). The annual catch is determined by annual fish growth, both natural and artificial (those fish that are stocked into waterways). It is important to point out that this fisheries management law is in essence based on principles of sustainability.

Fisheries management before the war emphasized 30% annual growth, due to both natural growth and artificial stocking. In other words, annual fishing trips in principle were not supposed to result in catching more than 70% of annual fish growth (Selimovic, 1991). This was only a management plan that was positive in theory. The reality, even

before the war, was that there was fish overharvesting, not only in the River Una, but in most of its tributaries including the River Krusnica (Harbas, H. 1997, pers. comm.).

Table 6-A The Maximum Number of Fish that May be Caught Daily

Brown Trout (*Salmo trutta m. fario*)	Three fish/day
Grayling (*Thymallus thymallus*)	Three fish/day
Danube salmon (*Hucho hucho*)	One fish/day or maximum of three fish/year
Pike (*Esox lucius*), Catfish (*Silukus glanis*) and Carp (*Cyprinus carpio*)	Three fish/day
Other species	Six fish/day

(Marjanovic, et. al., 1986)

Table 6-B The Minimum Length of a Given Species of Fish that May be Kept

Brown Trout (*Salmo trutta m. fario*)	25 cm
Grayling (*Thymallus thymallus*)	30 cm
Danube salmon (*Hucho hucho*)	70 cm
Tench (*Tinca tinca*)	18 cm
Barbel (*Barbus barbus*)	35 cm
Nase (*Chondrostoma nasus*)	20 cm
Catfish (*Silukus glanis*)	60 cm
Pike (*Esox lucius*)	40 cm
Chub (*Leuciscus cephalus*)	20 cm
Danube roach (*Rutilus pigus virgo*)	18 cm
Carp (*Cyprinus carpio*)	30 cm
Common roach (*Rutilus rutilus sarpathorossicus*)	15 cm
Perch (*Perca fluviatilis*)	15 cm

(Marjanovic, et. al., 1986)

Spawning times are taken into account with the management of fish species that are economically important. During the spawning times for certain fish species, fishing is prohibited (Table 6-C).

Table 6-C Fishing is Prohibited for These Species During the Following Time Periods:

Brown Trout (*Salmo trutta m. fario*)	October 1 - February 28
Grayling (*Thymallus thymallus*)	December 1 - May 15
Danube salmon (*Hucho hucho*)	January 1 - May 31
Pike (*Esox lucius*)	February 1 - March 31
Carp (*Cyprinus carpio*)	April 1 - June 31
Catfish (*Silukus glanis*)	April 16 - June 15
Nase (*Chondrostoma nasus*) and Barbel (*Barbus barbus*)	April 1 - May 15
Chub (*Leuciscus cephalus*), Danube roach (*Rutilus pigus virgo*), Common roach (*Rutilus rutilus sarpathorossicus*), Tench (*Tinca tinca*), Perch (*Perca fluviatilis*) and other species	April 15 - June 30

(Marjanovic, et. al., 1986)

Certain locations of the River Una and its tributaries are closed to fishing for either part of the year, or throughout the year. Decisions on this issue are made by the administration of collective OSFs that include all municipalities. The number of fishing trips, according to fishing laws of OSF, is limited. In a year, an adult member of the OSF can take up to 30 trips to the waterways, students can also take up to 30 fishing trips, and children age of 14 or under can take 20 trips annually (Marjanovic, et. al., 1986).

Stocking with fish fry is done depending on the financial resources available to a given OSF, rather than by the scientific base studies for fish populations (Harbas H., 1997, pers. comm.).

6.6.1 Artificial Bait for Angling

It is important to note that pre-war fishing regulations insist on angling with artificial bait (Selimovic, 1991). The same regulations apply presently, but many anglers use live bait and this clause of the fishing regulations is not enforced (Harbas, H. 1997, pers. comm.).

6.6.2 Targeting of Cyprinids Over Salomonids

Present fisheries management targets *Cyprinidae* (cyprinids) over *Salmonidae* (salmonids) (Selimovic, 1991). The fishing season is considerably longer for cyprinids than for salmonids and the daily catch for most cyprinid species is two times larger than that for salmonids. The present fisheries management encourages fishing for cyprinids in hope of enhancing the salmonid populations.

6.7 Reality of the Fisheries Management

The OSFs pass angling laws, but unfortunately these laws are not respected by all the members, nor by the majority of the public who fish. In most parts of Bosnia, the fishing method of catch-and-release is hardly known. The most common method is catch-and-keep even if the number of fish that one catches is over the limit or under the minimum size. In Bosanska Krupa, one fisherman told me that he knows of someone who caught 120 Danube salmon in the last year; the limit according to fishing regulation stands at three fish per year (Marjanovic, et. al., 1986). Unemployment and poor financial and economic situation forces a lot of fishermen to poach. Some of the anglers are war invalids who cannot do industrial work and depend on fishing for their livelihood. The 30 fishing outings per year limit is part of the fishing regulation, but no one abides by it. There are many people in Bosanska Krupa who fish every day during the fishing season (Harbas H. 1997, pers. comm.).

6.8 Problem of the "Commons"

Garrett Hardin's "Tragedy of the Commons" classically applies in the fisheries exploitation in northwestern Bosnia. Here we have a situation where an individual's gain from overusing the commons (i.e. waterway for fishing purposes) always outweighs individual losses due to its continuous degradation (Hardin, 1968).

Part of the problem of fisheries exploitation (besides the lawlessness during the war and economic depression after the war) is a lack of local control over the resources of waterways – something that has remained even after the failure of the old political system in 1990. Control of the waterways was left in the hands of the state, with little control at the local level. Richard O'Connor points out that local control is essential because "the environment itself is local; nature diversifies to make niches, enmeshing each locale in its own intricate web. Insofar as this holds, enduring human adaptations must also ultimately be quite local" (O'Connor, 1989). Local control of the fisheries resource is essential for successful management of that resource (The Ecologist, 1993). Only when fisheries receives local control will neighbors bring each other in line when someone is abusing the resource, as they all depend on the "commons" (i.e. the fisheries resource).

6.9 Exploitation of Fish

During the war, the exploitation of fish resources was great. There was no fishing regulation whatsoever and the majority of the people in northwestern Bosnia saw fish as one of their main food sources. The use of explosives to kill fish was extensively used in rives of the Una basin. Other unlawful fishing methods, such as fish nets, electric current and fish traps were also used. Fish population in all the water bodies of northwestern Bosnia has been greatly reduced and the over-exploitation of fish is continuing because of the very poor economic situation for most of the people in the region (Harbas H. 1997, pers. comm.).

6.10 Polluters of the River Una and its Tributaries

The polluters of the River Una (including those in the municipality of Bosanska Krupa and upstream from it) are:

On the River Unac (the name that is given to the River Una during its uppermost stage):

- "Fabrika za preradu papira" (Cellulose Industry) in Drvar
- "Metalija" and "Vrelo Une" (Metal Industry) in Srb

On the River Una:

- "Kombiteks" (Textile Industry) in Bihac
- "Kostela" (Hydroelectric Powerplant) in Bihac
- "Polietilenka" (Chemical Industry) in Bihac
- "Krajina metal" and "Energoinvest" (Metal Industry in Bihac)
- "Komrad" (Sewage Channel) in Bihac
- "Amratex" (Textile Industry) in Bosanska Krupa
- "Tvornica za preradu metala" (Metal Industry) in Bosanska Krupa
- "Fabrika tockova i vozila" (Automobile Industry) in Bosanska Krupa
- "Komunalno" (Sewage Channel) in Bosanska Krupa

On the River Krusnica:

- "Sipad" (Hog Farm) in Bosanska Krupa (Institute for Biology at the University of Sarajevo, 1984 and Ekonomski Fakultet Univerziteta u Sarajevu - Institut, 1996).

6.10.1 War Damage to the Industry

Most industries were heavily damaged during the war and are either not operating at all or are operating at a small percentage of potential. Therefore, pollution from industry is far less now than it was before the war (Marjanovic 1997, pers. comm.). The quality of water has improved since the factories were destroyed and this improved the health of fish species and other aquatic organisms. It is important when industry is rebuilt during future economic development, that new environmentally-sound technologies are introduced in the outface (i.e. emissions) stage of industrial production. Going back to

the pre-war technologies of industrial output would mean going back to unhealthy aquatic habitats.

6.10.2 Animal Farm and its Effects on the River Krusnica

A hog farm "Sipad" operated until the beginning of the war near the River Krusnica. Hog manure used to find its way through groundwater into the River Krusnica through the cave that is about 500 m from the source of the river. Presently, there are some plans to convert the already-existing facility into a sheep farm (Harbas F. 1997, pers. comm.). The waste management practice of any farm needs to be studied and problems addressed, because it may have consequences to overall fisheries management on the River Krusnica and beyond.

CHAPTER 7: BIOLOGY AND LIFE HISTORY OF GRAYLING

The European grayling (*Thymallus thymallus*) is a salmonid. Its distinctive features include a small mouth, a pointed head and a high and long back fin. The range of European grayling includes Central, Western and Northern parts of Europe (Figure 7.1). There are five other species that are found in northern America and Asia (Muus and Dahlstrom, 1978). European and Arctic grayling are considered to be different species, but their biology and life-histories are almost identical (Hamor 1998, pers. comm.). This is nicely explained in the article titled "Comparative biology and management of Arctic and European grayling (*Salmonidae, Thymallus*)" by Thomas G. Northcote (Northcote, 1995). I was able to research a lot of information in Canada on Arctic grayling and included the applicable information for grayling in northwestern Bosnia in this project. It is important to note that European grayling is better adapted to survive in adverse conditions than Arctic grayling (Hamor 1998, pers. comm.; Northcote, 1995).

7.1 No Evidence of Grayling Sub-populations in the River Krusnica

The grayling that lives in the River Krusnica is the same grayling that lives in the River Una (Harbas, F. 1998, pers. comm.). There is no evidence of the existence of sub-populations of grayling in the River Krusnica nor in the River Una. This is important from a genetics perspective because stocking will not alter the balance of sub-populations.

7.2 Habitat and Migrations

Grayling live in streams, rivers and lakes (Berry, 1998). Those that live in rivers and streams prefer clean, cold water. Grayling thrive in well-oxygenated open waters that are abundant with larval insects (Armstrong, 1986). These fish serve as a good indicator species of the quality of the aquatic environment. Grayling do not tolerate water pollution or habitat alteration very well (Marjanovic et. al., 1986). Grayling are also very sensitive to increased temperatures (Muus and Dahlstrom, 1978). Hydroelectric development that involves the building of dams significantly alters rivers and often

results in complete destruction of grayling populations (Muus and Dahlstrom, 1978). Those grayling that live in lakes prefer a habitat that is close to shore (Berry, 1998).

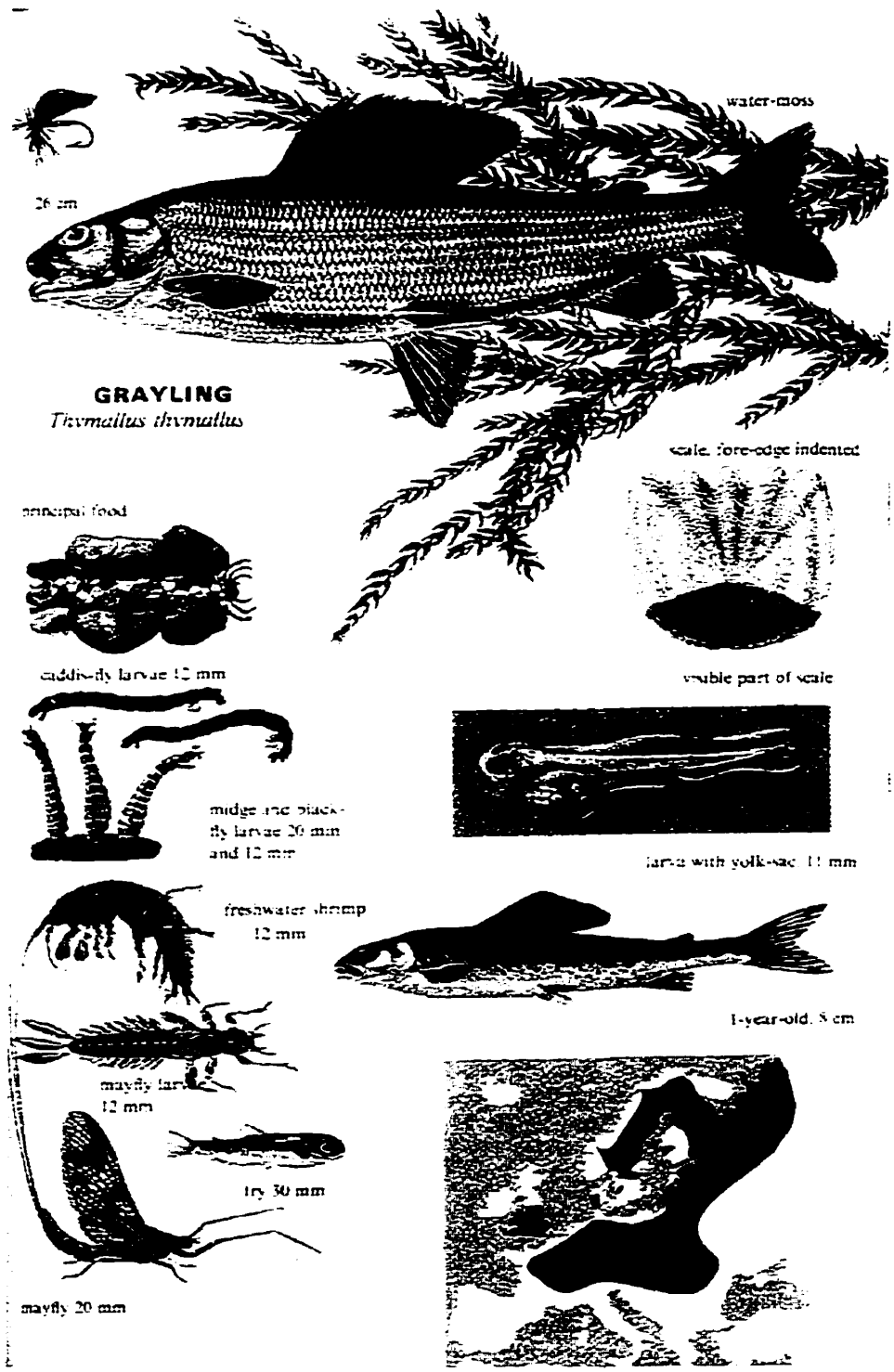


Figure 7.1 European Grayling (*Thymallus thymallus*) (Muus and Dahlstrom, 1978).

In many cases, grayling that live in rivers and streams use different waterways for different purposes (Armstrong, 1986). Spring-fed streams are mainly used for feeding. Bog-fed systems and shallow stream channels are used for spawning and feeding for the young, but not for over-wintering. Unsilted runoff water systems are used for all purposes, such as migration, feeding, spawning and over-wintering (Armstrong, 1986).

The River Krusnica falls into categories of both the spring-fed water system and the unsilted-runoff water system. The River Krusnica is used by grayling for migration, feeding, spawning and over wintering (Harbas, H. 1997, pers. comm.).

Grayling migrate to areas within the water system where there are deep holes and continual groundwater influx during the winter (Armstrong, 1986). Grayling also migrate for over-wintering from the headwaters of tributaries to the lower and deeper parts of the unsilted runoff water system. In some tributaries, they migrate downstream altogether into the main-stem river system (Armstrong, 1986). Distances that grayling cover during migration may vary with the water system variations. Some grayling may only have to migrate a few kilometers (e.g. in the River Krusnica) and others, (e.g. in some waterways of Alaska) have to migrate as far as 160 km to reach over-wintering sites (Armstrong, 1986).

In the River Krusnica, over wintering, feeding and spawning migrations are not extensive. However, resident grayling of the River Krusnica may migrate up to 10 km one way for any of the migratory purposes mentioned above (Harbas H. 1997, pers. comm.).

Depending on their age, grayling occupy different portions of the rapid-runoff rivers for feeding purposes. New-born grayling stay in the shallow waters, close to their spawning areas. Juvenile grayling include young fish that are one to three years old, and occupy lower portions of the rivers and their tributaries. The sub-adult grayling consist of those between four to six years of age. These fish, in most cases, occupy the middle portions of the rivers and their tributaries. The oldest grayling are those classified as post-spawning adults, and are found in the headwaters of the rivers and their tributaries. They also remain in these waters throughout the year except during the winter months when they migrate downstream to the deeper holes to over-winter (Armstrong, 1986).

Adult grayling use the same areas for feeding and spawning year after year (Armstrong, 1986). They always return to the same place for these purposes. In that respect, their annual site fidelity is part of their behavior.

7.3 Reproduction

It is believed that water temperature and flooding during spring are the two main factors that trigger grayling to spawn (Armstrong, 1986). Grayling prefer to spawn in small streams, but they also select certain areas within larger streams (Berry, 1998). It is noted by Berry that grayling spawn in the headwaters during times of high water discharge. During the years when discharge is low, they spawn in the lower stream areas. It is more advantageous for spawning to occur in the headwaters, as lower stream areas are more susceptible to flooding and therefore spawning is less successful in these areas in comparison to those in the headwaters (Berry, 1998). Populations of grayling in the northwestern Bosnia region spawn from the beginning of March to the end of April (Institute for Biology at the University of Sarajevo, 1984). In the River Krusnica, grayling spawn from the source of the river to the cave (1 km downstream) (Institute for Biology at the University of Sarajevo, 1984). Records were not kept on the number of fish that spawn in the River Krusnica nor in the River Una. Annual monitoring and recording of spawning activities was simply not done in the municipality of Bosanska Krupa for grayling nor for any other species of fish (Harbas F. 1998, pers. comm.).

In rivers and streams, grayling prefer to spawn in gravel (pea-sized minimum) or rocky bottoms (Nelson, 1954). According to Tack (1973), grayling prefer gravel with a diameter ranging from 0.08 to 38 mm (Tack, 1973). Grayling do not spawn on silt, nor in pools (Nelson, 1954). Furthermore, they prefer riffle areas of rivers and streams that have moderate-to-high gradients (Pasalic 1998, pers. comm.; Berry, 1998; and Armstrong, 1986).

Grayling movements triggered by spawning behavior occur at water temperatures between 0 °C and 6 °C (Berry, 1998). This coincides with the first melting of ice and snow in spring time which causes different degrees of flooding in rivers and streams (de Bruyn and McCart, 1974). According to Berry, males arrive at spawning areas before females. Larger males select the best riffle areas for spawning and defend those areas against smaller males or other intruders (Berry, 1998). Most of the time, females remain in deep pools and only come to the riffle areas to spawn in short periods (Armstrong,

1986). Spawning occurs from mid-day to sunset at water temperatures usually between 5 °C and 10 °C, even though temperatures can range between 2.2 °C and 16.7 °C. According to Tack (1971), male territories are oval in shape with dimensions of 183 to 244 cm in width and 244 to 305 cm in length. The average depth of water is 30 cm (ranges from 18 to 73 cm) and the average velocity of water is 79 cm/s (ranges from 34 to 146 cm/s). In his work, Tack (1971) descriptively explains the act of spawning:

> When a female comes into the riffle, males from territories near her erect their dorsal fins and move laterally toward her. The female may pass up several males before responding to a male display. A female responds by erecting her dorsal fin and moving laterally toward the displaying male. The undulations intensify as the fish come closer. As their bodies come in contact, the undulations become more intense, the male leans toward the female so his dorsal fin covers her back, and the male's caudal peduncle crosses over that of the female. The force of the male's caudal fin, working now in a vertical direction because of his body tilt and slight axial twist, drives the posterior portion of the female's body down into the gravel. After a spawning act the posterior third of the female's body is usually buried in the gravel. About halfway through the spawning act, the female opens her mouth widely, displaying the dark slash on her throat. The male also gapes, starting a second or two after the female (Tack, 1971).

"After a spawning act the posterior third of the female's body is usually buried in the gravel" describes the moment when the female buries her eggs in the gravel. The eggs are inserted between 2 cm and 3 cm into the gravel. Those that are not inserted deep enough into the gravel are washed downstream (Armstrong, 1986). The number of eggs laid by the females usually range from 600 to 8000, depending on their age (Muus and Dahlstrom, 1978). According to Jankovic, fecundity for grayling in the former Yugoslavia ranges from about 10,000 to over 31,000 eggs per kg of body weight (Jankovic, 1964). Maturity for females is generally achieved at three to five years, when at a length of 30 cm (Berry, 1998; Muus and Dahlstrom, 1978). Grayling spawn every year after they achieve maturity (de Bruyn and McCart, 1974). Generally, young mature females lay fewer eggs than the older ones (Armstrong, 1986). Grayling eggs are amber-like in color and measure from 2.5 mm to 3.5 mm in diameter (Muus and Dahlstrom, 1978; Jankovic, 1964). They hatch in three to four weeks depending on the water

temperature (180 to 200 degree-days) (Muus and Dahlstrom, 1978). After hatching, larval grayling measure about 8 mm in length and stay in the gravel for the first three to four days. During this time larval grayling feed on their egg yolk. Upon leaving the gravel, they emerge as swimming fry (Berry, 1998).

7.4 Young-of-the-Year

After leaving the gravel, young grayling move into areas of quiet water: the lower end of gravel bars, backwaters, side channels and grassy areas of adjacent sloughs (Alt, 1980). According to de Bruyn and McCart, young grayling form schools and stay in the above areas of quiet water until the end of the summer. In the summer, young-of-the-year grayling leave these areas and move into deeper waters as they become solitary and territorial fish. In the fall, most of the young leave headwater areas and migrate downstream to yet deeper portions of tributaries and into main-stem rivers (Armstrong, 1986).

Young-of-the-year which live in streams face high rates of mortality during flooding and drought. According to Nelson, grayling fry are helpless in water currents during their first two weeks (Nelson, 1954). This suggests that any significant flooding during this two-week period and probably later, may wash the young fry out of their calm and shallow water ranges. This in turn may be mortally detrimental to the young fry, directly due to the water turbulence and indirectly because the young fry may become food for larger predator fish (Armstrong, 1986).

Growth of grayling is very rapid during the first year. They can reach lengths of 7 to 12 cm during this time (Muus and Dahlstrom, 1978).

7.5 Food and Feeding Habits

During the early stages of their lives, grayling feed on zooplankton (microscopic animals) (Armstrong, 1986). Adult grayling mainly feed on larval and mature aquatic insects (Armstrong, 1986), such as caddis flies, dragonflies, mayflies, midges, and stoneflies (Berry, 1998; Muus and Dahlstrom, 1978). Grayling also feed on terrestrial insects, including ants, bees, beetles, grasshoppers, and wasps (Berry, 1998). Terrestrial insects play an important role in grayling's diet in streams that have dense vegetation on their sides (Armstrong, 1986). Snails, trout eggs that become exposed, small fish, and in some

cases small mammals (e.g. mice and shrews), are also part of the grayling's diet (Berry, 1998; Muus and Dahlstrom, 1978). Grayling feed from the water surface, mid-water drift, as well as from the stream bottom (Berry, 1998). They are active feeders and during summer months grayling feed on a 24-hour basis. The rest of the year, their feeding time preference is at dusk or in the darkness (Reed, 1964). In order to enhance their feeding effectiveness and competitiveness as a fish species, grayling often feed in schools (Berry, 1998). Breaking surface water as they feed on floating insects makes grayling interesting to watch from the shores.

Grayling often live in close proximity to other fish. According to Armstrong, very few studies have been done to date on interspecific competition for food. Research suggests that because grayling seem to survive on a variety of natural diets (i.e. benthos, zooplankton, aquatic and terrestrial insects, small fish and small mammals), they are not in a direct competition with any specific fish species (Armstrong, 1986).

7.6 Natural Predators

Pike (*Esox lucius*) and Danube salmon (*Hucho hucho*) are the two species of fish that feed on grayling adults in the rivers of northwestern Bosnia. According to Pasalic, pike (*Esox lucius*) are more successful than Danube salmon (*Hucho hucho*) in successfully catching and eating adult grayling (Pasalic 1998, pers. comm.). Brown trout feed on the eggs and fry of grayling (Hamor 1998, pers. comm.).

7.7 Aquatic Shelter

According to the study in 1984, grayling in the River Krusnica represented 23% of the overall fish fauna in spite of the presence of carnivores that include pike, brown trout and huchen (Institute for Biology at the University of Sarajevo, 1984). The observation that grayling do not successfully inhabit places where their natural predators are present, does not seem to hold true in the River Krusnica (Institute for Biology at the University of Sarajevo, 1984). The explanation for this discrepancy, according to Hamor, is that grayling in the River Krusnica can find shelter from predators during their sensitive ages (Hamor 1998, pers. comm.). In the River Krusnica, shelter for grayling includes aquatic plants and limestone depository rock. It is important that any fisheries management plan consider the importance of natural shelter. Natural shelter requires preservation in order to have high rates of fry survival not only for grayling but also for other species of fish.

7.8 Age

In Europe, male grayling mature at two to three years, whereas female grayling mature at three to five years (Muus and Dahlstrom, 1978). Their maturity is more related to their size than their age (Armstrong, 1986). Climatic differences affect the rate of growth in grayling. They tend to mature earlier in their lives in Southern regions such as Bosnia than in Northern places like Alaska. Growth rate is related to the availability of food throughout the year. According to a study conducted by Tack, most of the five year old grayling more than 290 mm long (fork length) were mature and most of those less than 290 mm long were not mature (Tack, 1974) (Figure 8.2). Fork length is defined as the length of a fish from the tip of the snout to the tip of the shortest median fin ray of the tail (or to the point where it is forked) (Ali, 1993). Most grayling mature at lengths between 290 mm to 300 mm (Armstrong, 1998). The size at full maturity, as Berry recorded, is 330 mm (Berry, 1998).

Fork length (mm)	Age (years)					
	5		6		7	
	No.	%	No.	%	No.	%
<250	2	0	—	—	—	—
250-259	4	0	—	—	—	—
260-269	5	20	—	—	—	—
270-279	2	0	2	0	—	—
280-289	4	25	4	25	—	—
290-299	6	67	1	100	—	—
300-309	1	0	4	75	1	100
310-319	—	—	6	100	1	100
320-329	1	100	2	100	2	100
330-339	1	100	3	100	2	100
340-349	—	—	—	—	5	100
>350	—	—	—	—	1	100

Figure 7.2 Lengths and Ages of Grayling from the Goodpaster River that were Sexually Mature (Tack, 1974).

In a reasonably productive habitat, grayling can live for more than a decade. Pressures imposed on grayling by sport fishermen are great in most places and do not allow grayling to survive into their old age. In the Firth River of Alaska, where harvesting pressures are minimal, the oldest grayling caught was 22 years old (de Bruyn and McCart, 1974).

7.9 Growth

According to a study conducted in a fish hatchery in Montana, newly hatched grayling ranged between 9.4 and 13.2 mm long, with an average length of 11.3 mm (Watling and Brown, 1955). During the first year, grayling growth depended more on the length of the growing season and the time of hatching than on water temperature and feeding patterns (Armstrong, 1986). Growth of young-of-the-year may vary considerably. Tack (1980) discovered that at the end of the growing season, the year-end fork lengths varied between 35 mm and 120 mm (Tack, 1980).

As expected, growth of grayling occurs mostly during the growing season. Growing seasons vary according to the latitude. In Alaska, the growing season for grayling is about three-months long (from mid-May to mid-August) whereas in Bosnia it lasts as long as six-months (from the beginning of April to the beginning of October). During the non-growing season, grayling experience some growth, but the growth is only one-tenth of that in the growing season (Riuski, 1967). Berry presents a generic annual pattern of growth for grayling in Alberta (Berry, 1998) (see Figure 7.3).

The longest grayling caught in Alberta was 51 cm, in the Namur River. The record for the heaviest grayling caught in Canada is 2.7 kg, 1.4 kg heavier than the 1.3 kg grayling caught in Alberta (Berry, 1998). The heaviest grayling caught in the northwestern region of Bosnia was 2.1 kg, measuring 76 cm (Pasalic 1998, pers. comm.; Selimovic, 1991).

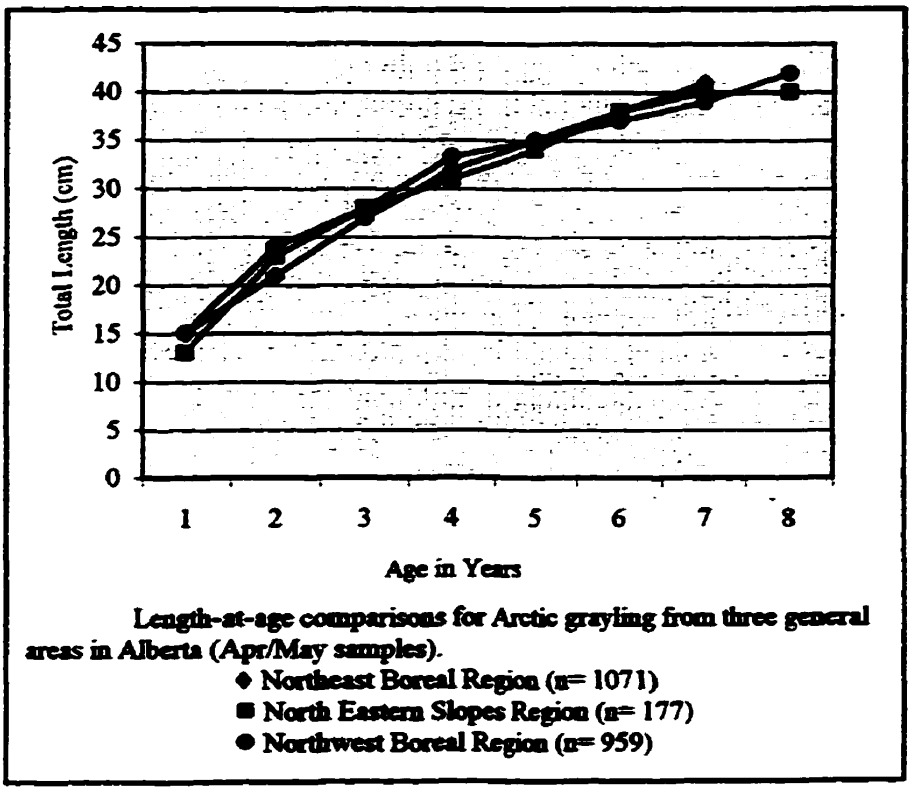


Figure 7.3 Length-at-Age Comparisons for Grayling from Three General Areas in Alberta (April/May samples) (Berry, 1998).

7.10 Angling Methods for Catching Grayling

As discussed in the section titled Food and Feeding Habits, grayling are competitive and intensive feeders. They are easily caught on dry or wet flies. Their behavioral traits cause them to go after most baits and lures. Some anglers in Bosnia catch grayling using bread as bait (Pasalic 1998, pers. comm.). Experienced stream and river anglers find grayling to be one of the most exciting fish to catch because of their fearsome fighting behavior once hooked. Grayling is considered to be a better "fighting fish" than any trout species found in Bosnian rivers (Harbas H. 1997, pers. comm.).

7.11 Aging Techniques

There are two main methods for determining the age of grayling. One is to look at their scales and the other is to look at their otoliths (ear stones) (Muus and Dahlstrom, 1978).

Armstrong (1986) argues that the otoliths method is better in determining the exact age of a fish because otoliths develop annually throughout a fish's life (Armstrong, 1986). Determining the age of older fish using the scale method may not be precise because "the growth rate slows and the consequent crowding of circuli forms a dense edge" (Roguski and Winslow, 1969). This causes fish-biologists to underestimate the age of older grayling (Armstrong, 1986). The two methods give similar results until the age of eight. According to the study conducted by de Bruyn and McCart, the ages of fish determined by the otoliths method were 22 and 15, as opposed to 14 and eleven using the scale method (de Bruyn and McCart, 1974). Furthermore, formation of scales does not occur for grayling until they reach a fork length of 35 mm. Some young-of-the-year grayling do not reach this length in their first year, thus failing to develop scales in the first year of their lives. This phenomenon needs to be considered when aging grayling by using the scale method (Armstrong, 1986).

CHAPTER 8: AQUACULTURE: SUSTAINABLE DEVELOPMENT PILOT PROJECT

8.1 Sustainable Development

The term "sustainable development" was first introduced by the World Commission on Environment and Development (the "Brundtland Commission") in 1987. It was defined by the Commission as: "material improvement to meet the needs of the present generation without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987). Many argue that even though the phrase suggests our ethical responsibility to future generations, it stops short of defining what our "needs" are and those of the future generations – an important component in evaluating the idea of sustainable development.

A more useful definition of sustainable development may be found in Herman Daly's book titled Beyond Growth. His definition of sustainable development gives us a common basis for action. According to Daly, sustainable development is development without growth in throughput that exceeds the regenerative and absorptive capacity of the environment (Daly, 1996). We should keep this definition in mind when implementing the proposed aquaculture facility because the goals and objectives of the project are imbedded in the definition of sustainable development.

8.1.2 Sustainable Aquaculture

The proposed aquaculture should be a sustainable development project and needs to be planned and managed as such. According to Corbin and Young (1997), sustainable aquaculture should:

- conserve natural resources and biodiversity
- achieve the least degradation of the environment
- utilize techniques and technologies appropriate to a situation and site

- generate profit or economic benefits in excess to costs
- foster minimal social disruptions and conflicts
- provide for community needs

(Corbin and Young, 1997).

8.2 Hatchery Survival

According to Locke's study on Atlantic salmon (*Salmo salar*), removal of adults from the wild population for use as hatchery broodstock was beneficial to population growth if the survival rate of their hatchery-reared progeny was 10% or more of that of wild-reared juveniles and adults thereafter (Locke, 1998). Similar results are expected with grayling in this regard (Hamor 1998, pers. comm.). The proposed grayling hatchery is recommended because better survival of grayling is expected in the hatchery than in the river itself (Hamor 1998, pers. comm.).

8.3 Maintenance of Genetic Diversity

In the first phase of the proposed grayling hatchery operation, grayling should be raised mainly for rehabilitation purposes of the River Krusnica and its receiving river (the River Una). Some of the grayling may subsequently be raised for the marketplace. Capture of wild ripe grayling for purposes of stripping of eggs and fertilization should be done from the River Krusnica itself. This would ensure that artificially raised grayling is not significantly different in terms of the genetic make-up from the wild grayling in the river (Hamor 1998, pers. comm.; Monita 1998, pers. comm.). The wild grayling should be released back to the river and the next year other wild grayling should supply their genetic material. This would prevent inbreeding from occurring and ensure that genetic diversity is preserved (Monita 1998, pers. comm.; Hamor 1998, pers. comm.). Adult spawners should be tagged before being released back into the River Krusnica. This way, some type of record can be kept in order to keep track of grayling gametes.

8.4 Egg Supply and Incubation

Grayling gametes can be collected from adult spawners in the River Krusnica during the first week in March (i.e. spawning period in northwestern Bosnia). Adult spawners may be caught using gill and seine nets at spawning sites in the river. After this process, the captured wild fish must be released back into the river. Tagging of these fish is recommended in order to keep a record of the parent fish (Monita 1998, pers. comm.). This is especially important for genetic diversity, since the same fish might be used for artificial fertilization in the future (Hamor 1998, pers. comm).

Eggs can be artificially fertilized in a container at the riverbank and transported to the proposed location of the aquaculture facility. There the incubated eggs need to receive a steady supply of spring water (recommended temperature of 4.8 °C and oxygen content of 83%). It is also recommended that eggs be treated once with the fungicide malachite green (Carlstein, 1993).

8.5 Holding Conditions

According to Carlstein (1993), rearing tanks with dimensions of 1 m by 1 m can be used for approximately 2500 grayling fry after they have been hatched. The water depth in rearing tanks should be about 30 cm. The water flow should be 3 L/min and should consist of river water (90%) and spring water (10%). In order to maintain a healthy environment for grayling fry, dead eggs and fry need to be siphoned off (Carlstein, 1993). Monitoring of the rearing environment (counting of dead eggs and fry) should also be part of the daily procedure in the proposed aquaculture facility.

8.6 Feed and Feeding Methods

The main reason for not having a fish hatchery for grayling in Bosnia is because this fish requires a special feed in its early stages of life (Brankovic 1998, pers. comm.). Unlike trout fry that feed on standard fish feed, grayling fry require special fry feed that can be bought in Western Europe. It may also be raised on live food that includes zooplankton and brine shrimp (*Artemia*). The following section addresses feeding issues of grayling fry - considered by many to be the main obstacle in raising grayling artificially. Past the early life-stage (first four months), grayling can be fed with the same artificial feed used in trout rearing and is available commercially in Bosnia (Hamor 1998, pers. comm.). If

the right food is available in the early stages for grayling fry, raising them is not any more difficult than raising trout and the success in survival is comparable (Hamor 1998, pers. comm.).

8.6.1 Feeding of Grayling Fry

Live or frozen plankton is considered to be the main component in starter diets in artificial rearing of grayling (Ocvirk and Vovk, 1986). However, recent experiments have shown that artificial dry starter foods have been equally effective as starter diets in aquaculture rearing environment for grayling (Carlstein, 1993). It is important to note that grayling fry start feeding four to eight days after hatching (Brown and Buck, 1939).

8.6.2 Live Food for Grayling Fry

Two types of live food have proved most successful in rearing grayling fry in artificial environment. They include zooplankton and brine shrimp (*Artemia*) (Carlstein, 1993). Other live foods include larvae and midges (Muus and Dahlstrom, 1978). However, larvae and midges may not be suitable in the earliest life-stages of grayling fry.

Zooplankton can be collected from littoral zones of a river using a plankton net (mesh size 100 μm). Zooplankton may consist of eggs, nauplii and adults of species such as *Bosmina* sp. and *Polyphemus pediculus*. The size varies between 100 and 1,800 μm (Carlstein, 1993).

Brine shrimp (*Artemia*) diet may include a mixture of newly hatched brine shrimp and cysts of brine shrimp. Their size varies between 220 and 490 μm (Carlstein, 1993). Dry brine shrimp cysts can be purchased commercially from a number of different European suppliers, such as Ocean Star International Inc. Dry cysts can hatch in an artificial sea-water medium at 28 °C ±0.5 °C (Teramoto and Kinoshita, 1961). They require 3‰ salinity (Carlstein, 1993). *Artemia* cultures grow faster in darkness than under bright-light conditions, and should be provided with as much darkness as possible (Sorgeloos, 1973). Brine shrimp larvae can be cultured in glass or plastic containers (Figure 8.1)

The volume of the containers can be between 1 L and 30 L with concentrations of 1 to 2 larvae per ml. This means that a 1-L container can accommodate 2000 larvae or a 30-L container can accommodate 50,000 larvae (Sorgeloos, 1973). *Artemia* culture needs to

be aerated by air-bubbling one minute every half hour. Air pumps could have an electric clock to perform this function. *Artemia* cultures should be fed twice a day with algae such as *Scenedesmus* that can be purchased in dry powder (Mikrozell, Dohse Aquaristik, Bonn, Germany).

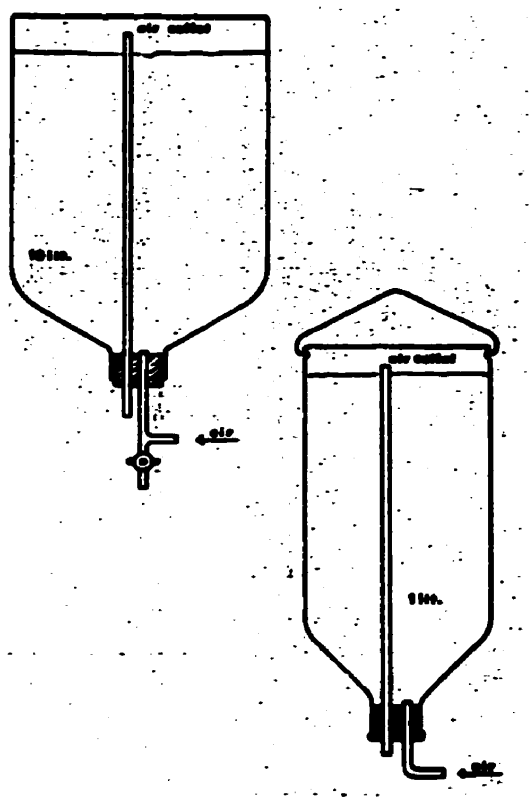


Figure 8.1 Sketches of 1 L and 10 L Culturing Bottles (Sorgeloos, 1973).

8.6.3 Artificial Food for Grayling Fry

According to the experiment conducted by Carlstein (1993), four artificial diets can be used to rear grayling fry successfully. They include: (1) Aquastart, size 0 (150-300 μm, Ewos, Finland), (2) the fry feed Kyowa B-400 (250-400 μm, Kyowa Hakko Kogyo Co., Ltd, Japan), (3) experimental food prepared by the Institut National de la Recherche Agronomique (INRA), St-Pee-sur-Nivelle, France and (4) Tess, Edel perler 300 μm (Skretting, Norway) (Carlstein, 1993).

Table 8-A Characteristics of Different Feeds, Both Live and Artificial (Carlstein, 1993).

	Artemia	Zooplankton	Aquastart	Kyowa	INRA	Tess
Protein	61.0	71.2	64.0	57.0	50-51	55.0
Fat	4.4	19.3	13.5	23.1	9-10	15.0
Carbohydrate	ND	9.5	3.0	ND	ND	11.0
Ash	4.4	ND	11.5	7.8	ND	9.9
Water	8.9	ND	8.0	4.1	13-14	9.0
Diameter	220-490	100-1800	150-300	250-400	200-630	300

Note: General content (% of dry matter)
Diameter (μm)
ND means not determined
The chemical composition for zooplankton is expressed as a percentage of the total organic matter, excluding chitin
(Carlstein, 1993).

8.6.4 Quantity of Food for Grayling Fry

Zooplankton occur naturally in the River Krusnica and should be part of the overall feed for young grayling. Additional zooplankton could be collected twice daily from the river with a plankton net (mesh size 100 μm) to feed the fry.

Brine shrimp need to be hatched daily if used as food for young grayling. For the first two weeks, natural food (brine shrimp or zooplankton) need to be fed to grayling fry four times a day (Carlstein, 1993).

In an experiment performed by Carlstein (1993), 2500 grayling fry were fed 15 g per day dry weight of recently hatched *Artemia* during the first week, and 43 g per day during the second week. Another test group of grayling fry (2500) were fed 7.5 g and 40 g per day during the first and second weeks. Those that were being fed on additional zooplankton were given an average of 3,555,000 plankton per day during the first week and 8,658,000 plankton per day during the second week (Carlstein, 1993).

After the first two weeks, grayling fry can be fed with dry food (e.g. Aquastart). Feed ratios need to be adjusted once a week in order to have *ad libitum* feeding. Furthermore, food particles used in feeding need to be adjusted according to fish size. Holding tanks must be cleaned daily and dead fish must be removed. After the second week, the water flow in tanks needs to be increased to 5 L/min.

8.6.5 Recommendations for Feeding Grayling Fry

Carlstein (1993) discovered that mortality rates were significantly reduced when feed for grayling fry was changed from live to an artificial diet, than when changes were being made on artificial diets. This finding suggests that artificially reared grayling that are meant to be stocked in rivers, should be fed live diet or artificial diet containing different particle sizes and shapes. This feeding procedure would ensure a higher rate of survival for artificially reared grayling fry released into the wild.

8.7 Expected Weights and Lengths

Carltein's (1993) grayling fry experiment in Sweden achieved a mean weight and length of 8 g and 10 cm from June 13 to October 10 (Carlstein, 1993). Slightly higher weights and lengths for grayling can be expected in northwestern Bosnia because of the earlier spawning time and longer growing season there.

8.8 Caging

In September, grayling fry can be placed into cages. They can be kept in cages throughout the winter months because natural food may not be abundant. Grayling fry can be fed in cages during the winter months and released in the spring. The caging time for grayling may be six months or longer (Hamor 1998, pers. comm.). This can only be determined by local trials (Hamor 1998, pers. comm.). If the shelter theory (good natural shelter in the River Krusnica) proves to be true, grayling will have a good chance of survival when released.

8.8.1 Negative Effects of Caging

Negative effects of caging can be significantly reduced or eliminated if the following procedures are observed:

The density of grayling in cages needs to be formulated in such a way to provide an optimum condition for fish survival. The primary objective in the proposed fish hatchery is the survival of grayling fry so they can be returned to the river. Many commercial operations are more concerned about maximum productions and therefore fish densities are very high. When fish densities are high, there is a high chance of disease development. In cases where disease spreads, fish are commonly treated with antibiotics. Treatment with antibiotics is problematic because it can serve as breeding ground for antibiotic resistant bacteria that can also harm the fish (Hamor 1998, pers. comm.). In the proposed fish hatchery, fish densities will be optimized for fish survival and antibiotics will not be used. Therefore, this concern does not apply.

Another concern about cage culture is that food rots below cages. This effect may be significantly reduced because artificial feeding would be supplemental (natural food in the river will be available) and given in small quantities. It is important to remember that the aim of the project is for optimum survival and not necessarily for optimum growth (Hamor 1998, pers. comm.). Other preventive measures for this problem may be to introduce such practices as collection of debris and planting organisms such as crustaceans and molluscs that can reduce or eliminate the food debris. Danube roach (*Rutilus pigus virgo*), barbel (*Barbus barbus*), chub (*Leuciscus cephalus*) and nase (*Chondrostoma nasus*) are all present in the River Krusnica. They are all likely to feed on the food debris that settles on the bottoms of cages. All of the variables mentioned in regard to the problem of fouling may be tested in an actual setting of the River Krusnica hatchery.

8.9 Release of Young Grayling into the River Krusnica

After one year, at lengths over 12 cm, young grayling can be released in the river (Muus and Dahlstrom, 1978). This should happen in the River Krusnica in early spring. During the spring months, there is an abundance of food for fish and this increases the survival chances for young grayling.

8.10 Predators and Parasites

Fish have their own natural enemies ranging from mammals through birds to insects. The proposed aquaculture facility should recognize predators and parasites and make sure

that they do not significantly threaten the fish that are being raised. There are a number of predators and parasites that live in northwestern Bosnia and may pose a threat to fish in the proposed aquaculture.

Water shrew (*Sorex palustris*) is an excellent swimmer that lives in deserted burrows near the water. Its diet includes fish fry and fish eggs.

Otter (*Lutra lutra*) is an aquatic carnivore with nocturnal habits and thus is not commonly seen by humans. Its presence can be identified by its broad foot prints which show webbing on its feet. Otters are excellent hunters of fish. It has burrows in the river-banks with the entrance below the water-level.

Kingfisher (bird - order *Caraciiformes*, family *Alcedinidae*) eats fish fry by diving into the water. It nests in river banks.

Water shrews (*Sorex palustris*), otters (*Lutra lutra*) and kingfishers (bird - order *Caraciiformes*, family *Alcedinidae*) may all be predators to fish that are contained in the cages of the proposed aquaculture facility.

Dragonfly larvae (insect - order *Odonata*, suborder *Anisoptera*), **water beetles** (aquatic beetle - order *Coleoptera*, family *Amphizoidae*) and the **water-boatman** (insect - order *Heteroptera*, family *Corixidae*) all feed on newly hatched fish fry and should be screened out at the point of water intake to the proposed aquaculture facility for newly hatched grayling fry.

Fish leeches (genus *Argulus*) are parasites that suck the blood of both the newly hatched fish fry and the older fish. At the proposed aquaculture facility, the leeches may be narcotized with 2.5% solution of common salt before they are removed (Muus and Dahlstrom, 1978; Encyclopaedia Britanica, 1998).

8.11 Effluent Management

The proposed aquaculture facility is a small-scale operation that would not have a significant effluent production. During the period of caging, waste collection is almost impossible. Good waste management in the aquaculture facility itself (i.e. during the

beginning growth stage of grayling development) should be introduced. Waste should be filtered out before the water is discharged into the river. This way, downstream nitrification is avoided. Filtered effluent waste could be given to the local farmers who may choose to use it as a fertilizer on their gardens. If the facility is expanded in its operational capabilities and the amount of waste significantly increases, waste management issues need to be studied and addressed more carefully.

8.12 Operations

The proposed aquaculture facility, as discussed in Chapter 2, may provide employment for a number of war invalids. The exact number of employees can be worked out in the future when needs of the operation become clearer. However, the proposed facility will need to have a manager of operations. Staff of the aquaculture facility must include at least two or three people, with at least one person present in the facility at all times (Hamor 1998, pers. comm.). There also needs to be an administrator who can be responsible for the education and outreach components of the operations.

8.13 Local Contribution

In order to fund a given development project, many international aid organizations look for local contributions to the project (Kannan 1997, pers. comm.). The proposed aquaculture project could include local contributions such as the provision of land, building materials (e.g. gravel, wood, cement), electricity, construction machinery and manual labor. International aid organizations could provide the funds to pay a consultant to design and build the proposed aquaculture facility and buy the necessary equipment and materials to raise the fish (e.g. fish cages and fish food). An interested implementation partner should be willing to financially support the project for at least two years, until the project can become self-sufficient and revenue-producing.

8.14 Education at the Aquaculture Facility and Beyond

Education will need to be included in the overall goals and objectives of the proposed aquaculture facility. Fisheries educational strategy should include six themes:

- Habitat conservation and protection
- Fish biology and life history

- Using the fisheries resource
- Stewardship
- Fisheries management
- Aquatic ecology

  (Grieef 1998, pers. comm.).

It may be beneficial to include an interpretive center at a later stage to enhance the community's knowledge of the themes that directly relate to the fisheries management. The staff of the proposed aquaculture facility will need to be involved in outreach activities in the municipality. They must make the community aware of the problems facing the fisheries and pass on ideas and general knowledge regarding the possible solutions. The community must realize that waterways are the "commons" and they belong to them. They must be stewards of the "commons" and protect them. Staff of the proposed aquaculture facility must work hand in hand on these issues with the OWI, the TU, the MDC, the relevant Cantonal Ministries (i.e. the Ministry for Education, Science, Religion, Culture and Sports and the Ministry for Regional Planning, Environment and Reconstruction) and all of the other relevant stakeholders.

CHAPTER 9: MANAGEMENT PLAN RECOMMENDATIONS

Alteration and loss of habitat and overharvest are the two main reasons for the reduction of grayling populations (Berry, 1998).

9.1 Habitat Alteration

Many activities can result in the alteration of grayling habitat, including: oil, gas and mineral exploration and extraction, industrial and recreational developments, road and pipeline construction, farming and cattle grazing, and timber harvest (Finley, 1998; Berry, 1998). All of these activities can cause siltation, erosion and removal of vegetation cover on land and in streams, thus negatively affecting fish shelter, food production, and spawning and nursery areas (Berry, 1998). Alterations in the waterways can cause flash floods in the spring that can wash grayling eggs and juvenile fish from their nursery areas (Berry, 1998).

9.2 Overharvest

The overharvest of grayling, and other fish, is a major limiting factor of species production in Bosnia (Harbas, H. 1997, pers. comm.). Grayling is caught easily by anglers because of its aggressive feeding habits (Berry, 1998). Furthermore, inadequate protection and monitoring of fish, the harvest of grayling in northwestern Bosnia overwhelmingly exceeds the number of fish that can be produced in these waterways. Overharvesting has contributed to the decline of grayling in most areas of the waterways, and complete loss in others (Harbas, H. 1997, pers. comm.).

9.3 Management Policy

For successful fish management, an overseeing organization needs to develop a clear mission statement. In the case of Bosnia, the mission statement needs to come from the OSF that is responsible for the management of fish in the waterways. The mission statement for the Fisheries Management Division in Alberta is:

> "To sustain the abundance, distribution and diversity of fish populations at the carrying capacity of their habitats" (Fisheries Management Division, 1997).

A similar statement needs to be developed and followed in Bosnia.

According to Berry, the successful conservation of fish is two-fold:

> "Protection which ensures the perpetuation of abundant fish populations." **and** "The appropriate use of only the surplus that is not required for population maintenance." (Berry, 1998).

Only with successful conservation of fish populations can we support the social and economic benefits that anglers receive from fishing. Sustainable management of fish resources includes three points:

1. Habitat Maintenance - sustain quality and quantity of fish habitat.

2. Fish Conservation - monitor and regulate fish harvest so it does not exceed the natural reproduction.

3. Fish-Use Allocation - management that will meet the present needs of anglers without compromising future generations of anglers (Berry, 1998).

The following principles should be incorporated into the overall fish management policy in order to have a sustainable fish resource:

1. No loss of natural habitats for fish.

The natural habitat for fish must be preserved. Development or any other activity in a manner that may cause habitat alteration should be avoided (Berry, 1998).

2. Fish populations should be reproducing in their natural habitats whenever possible.

Fish hatcheries are not the complete answer to sustainable fish management. They can help increase the number of fish in waterways where populations of fish have declined

drastically because of overharvest (as in the case of the River Krusnica). Reproduction of fish in natural habitats is biologically sound and cost effective (Berry, 1998).

3. Preservation of biological diversity is essential.

Preservation of biological diversity of all fish populations is important because it helps preserve a healthy aquatic ecosystem. Particularly, the native fish species, populations, sub-populations and the unique strains that have evolved in certain waterway areas over hundreds of years must be maintained (Berry, 1998). Introduction of non-native fish species should be avoided because they may have a negative impact on the established aquatic ecosystem.

4. Scientific information on fish populations and their habitat is necessary.

In order to achieve the goals of fish conservation, habitat maintenance and fish-use allocation, it is important to have credible scientific data on fish numbers, growth rates, production rates, harvest rates and fish habitat needs (Berry, 1998). Managers must take into account the scientific information obtained from scientists.

5. Education and involvement of the public in fisheries management is needed.

Anglers need to be better educated and more involved in the fisheries management process. Public forums, lectures, literature and educational seminars on successful fisheries management are needed. As is done for driving, an exam should be required before a fishing license is issued (Berry, 1998).

6. Financial support from the users is expected

Anglers and stakeholders who directly benefit from fish and water resources need to contribute financially in order to keep the management of fisheries sustainable. This can be done through increasing the fee associated with licenses and permits (Berry, 1998).

9.4 Habitat Maintenance Goals

According to Berry, maintenance of grayling habitat is a function of habitat protection, habitat rehabilitation and habitat development. Habitat protection means to protect

grayling habitat in order to maintain and support populations of grayling. Habitat rehabilitation means to alleviate the negative impacts imposed on grayling habitat and repair damaged grayling habitat. Habitat development refers to creating grayling habitat on sites where grayling populations can increase (Berry, 1998).

9.5 Habitat Maintenance Strategies and Actions

Overall protection of grayling habitat, especially areas used for spawning and rearing, is necessary for successful habitat maintenance.

Migration routes for grayling must be identified and free from blockages. Waterway blockages, such as dams, must be absent in the waterways that are used by grayling for migration. Waterway blockages cause population fragmentation and in turn may result in extinction.

Habitat enhancement projects directed at increasing the cover and stability of stream banks and improvement of spawning and rearing areas can significantly improve habitat for grayling and other species. Habitat protection guidelines need to be established so that physical disturbances to the watershed resulting in disturbance of streambank vegetation, altered quality and temperature of water, sedimentation, or increased nutrients loads, are avoided (Berry, 1998).

Upstream works, that divert and remove water from the waterway, may have significant impact on grayling habitat. Therefore, restrictions are required to maintain grayling habitat. Proponents of development activities causing alteration of grayling habitat should rehabilitate those altered habitats to their original capacity. Water resource management should take into account that grayling and other fish are also users of water. Habitat maintenance and fish conservation should be incorporated in the overall planning process of water resource management (Berry, 1998).

9.6 Fish Conservation Strategies and Actions

Each body of water has a given productive capacity. In other words, it has a limit to fish biomass and cannot naturally exceed that limit. Fish biomass can include a combination of fish sizes. Significant numbers of mature fish must be present to achieve good rates of reproduction. Natural reproduction is more beneficial than stocking. Alleviation of

fishing pressure and habitat maintenance are the two most important components of fish conservation (Berry, 1998).

Increase of the number of grayling through natural reproduction will occur by protecting populations of grayling. Regulation of harvest according to age is a component of the overall protection goals. Harvest of grayling that have not achieved their maturity should be restricted in order to increase the number of spawning adults. Furthermore, harvest should only be permissible for fish that have achieved maturity plus one year (i.e. grayling at approximately 35 cm). In the case of grayling, this means allowing fish to live for five years, because most grayling achieve maturity in their fourth year (i.e. most grayling mature at 30 cm) (Armstrong, 1998).

Control and regulation of access to fishing areas is another way to relieve the pressure posed by anglers and to help restore the affected fish populations. Certain areas of waterways can be closed for fishing during a given time. Restricting public access to remote areas can also be beneficial in restoring grayling populations (Berry, 1998; Selimovic, 1991).

Education of the public is a very important component of grayling conservation. The OSF and other stakeholders should share information and ideas. Stakeholders should also be involved in joint studies relevant to fish conservation. Education on the subject would benefit the overall conservation strategy.

9.7 Fish-Use Allocation Strategies and Actions

Species of fish that are higher in population should be harvested, rather than grayling or other species that are fewer in numbers (Berry, 1998). Fish management policies should encourage catch-and-release (0-limits) fishing, allowing harvest only with strict limits on the number of fish. Anglers need to be proficient in proper ways of releasing fish, so that the mortality rate is reduced. Furthermore, the use of bait and treble hooks for the fishing of grayling should not be allowed. Finally, grayling fishing for purposes of tournaments or derbies should not be allowed (Berry, 1998).

Educational and viewing opportunities by the public should be encouraged, for example where the public can see grayling spawn or feed. Locations for viewing could also provide educational facts on grayling via signs and/or brochures.

9.8 Education Strategies and Actions

Public involvement is an extremely important component of successful fisheries management. Volunteers should be included in habitat development and restoration projects. By having the public involved, projects become the foundation for excellent educational opportunities. Furthermore, volunteer activities become part of the recreational experience.

Stakeholders (i.e. industry, anglers, various levels of government, and non-government organizations) need to learn the biological requirements and other facts pertaining to grayling conservation. This will encourage all stakeholders to accept regulations that are relevant to grayling management (Berry, 1998).

Environmental NGOs such as "Zeleni" and "Unski smaragdi" in northwestern Bosnia, that are committed to protecting grayling and other fish species, should also be involved in the education of school children. Lectures, seminars, and extra-curricular activities that promote the well-being of fish should be encouraged.

Grayling-enhancement projects, such as improvement of spawning and rearing areas, removing stream blockages, and improvement of bank cover are a few examples of projects in which the public can participate.

Industrial developers that adversely affect waterways and grayling habitat should provide funding for research and impact assessment relevant to fisheries management. This would greatly benefit the overall knowledge base in this area.

9.9 Enforcement Strategies and Actions

Education on fishing laws and regulations for the public is the first step in successful enforcement. Before a fishing license can be issued, a test should be administered by the OSF. Those that pass the exam should be made aware of critical issues pertaining to fisheries management and the laws that guide them (Berry, 1998).

FEOs should have authority in the enforcement of laws that pertain to fisheries management. They should have an attractive salary financed from the revenues collected

from the membership of the OSF, to act as a deterrent to bribery. If a FEO receives bribes, he or she should be fired.

Courts need to prosecute those who violate the fishing regulations. Furthermore, they need to levy higher fines for those who commit serious fishing offenses (Berry, 1998).

Enforcement among members of the OSF is necessary. Those who see poaching or other unlawful fishing activity should report it to the FEO or the OSF. Enforcement should be especially strict during spawning periods.

9.10 Inventory, Monitory and Research Strategies and Actions

An inventory of fish stocks (i.e. information on their number, growth, production rate, harvest rate) is important in achieving habitat maintenance and fish conservation goals. Fishing organizations should be working together with consulting organizations on establishing good and timely information on fish stocks (Berry, 1998).

It is important to gather information on the effectiveness of regulation, habitat protection and rehabilitation directly related to grayling as well as other species of fish. More research is necessary in understanding movements and critical habitat requirements for grayling and other species. Research in determining the harvestable surplus is also required to better establish the daily catch limits.

Further research needs to be done on hooking mortality caused by hooks with bait, barbed hooks and treble hooks vs. barbless hooks (Berry, 1998).

Monitoring the interaction between land-use impacts and natural events is needed to better understand how they limit or enhance grayling populations (Berry, 1998).

9.10.1 Spawning Records and Monitoring

Records are not kept on the number of fish that spawn in the River Krusnica nor in the River Una. Annual monitoring and recording of spawning activities was not done in the municipality of Bosanska Krupa for grayling, or for other species of fish (Harbas 1998, pers. comm.). This should change and the OSF should pursue a more active role in this

respect. Annual records on the number of grayling (as well as other species of fish) should be kept. Through this kind of monitoring, the OSF would have a better idea of the annual recruitment for specific species of fish to aid in the fisheries assessment of waterways and enhance overall successful fisheries management.

9.10.2 Monitoring and Recording of Spawning Activity

In some instances, trout dig a redd (or nest) and one can simply count the redds to get an idea of the location and level of spawning (Clipperton 1998, pers. comm.). Unfortunately, grayling do not build nests. The only other real option is to set up fish traps on the spawning streams to catch the spawning migration in early spring and actually count the number of fish (usually tag, measure the length and weight, and with grayling, you should be able to tell the sex) that are going to spawn. This is a long-term study that would need to be done over a number of years to determine the trend. This is dependent on gaining permanent access to a good location on a spawning stream (Clipperton 1998, pers. comm.). Another possibility is to simply set up a monitoring location where one could watch the spawning activity in the stream and count the number of fish that come to spawn over the spawning period.

9.11 Improvements in Sportfishing Regulations

9.11.1 Sportfishing Season

The season for harvesting grayling needs to be reduced in northwestern Bosnia. According to the fishing regulations there, grayling can be harvested any time other than the period between December 1 to May 15. That is the only closure imposed by fishing regulations. Introduction of catch-and-release fishing (0 limit) could be introduced during the fall to allow fishing, but prohibit harvesting. A catch-and-release season could be introduced between September 01 and November 30; the harvesting season could be between May 16 and August 30.

9.11.2 Minimum-Size Limit

According to the present regulations, the minimum-size limit for grayling in northwestern Bosnia is 30 cm. This should be changed to 35 cm to allow greater numbers of grayling to survive to maturity. Grayling usually mature at the age of three to four when they reach a length of about 30 cm. Allowing grayling an extra year to live in their mature stage would mean a greater number of them spawning, thus increasing the number of offspring and improving natural reproduction rates.

9.11.3 Daily Catch Limit

Three grayling can be kept per day during the angling season in northwestern Bosnia. The daily catch limit should be reduced to two or one fish. The reduction will help to alleviate the pressure from overharvesting, while at the same time distributing more equitably the available harvest among anglers.

9.11.4 Catch-and-Release Fisheries (0-limits)

Those anglers who do not depend on fish for food should practice catch-and-release fishing throughout the angling season. Throughout Bosnia, it is rare for anglers to release fish. This mentality needs to be changed to reduce the harvesting pressure on grayling and other fish species.

Certain watersheds or sections of them should be designated as areas for catch-and-release angling only (Berry, 1998). This would relieve the harvesting pressure completely and help the overall rehabilitation process of the waterways.

9.11.5 Legal Methods

Only angling using a "lure" should be allowed in the waterways of northwestern Bosnia. A lure is defined as: "spoon, plug, jig, fly, spinner or other such device made only of feathers, fiber, rubber, wood, metal, plastic or similar materials, and does not attract fish by scent or flavor (Alberta Environmental Protection, 1998)".

Spearfishing, bowfishing, baitfishing, snagging, use of snares, firearms, other explosive devices, electrical current, fish traps, nets, lights to attract the fish, should all become

illegal fishing practices, as should "chumming". Chumming means throwing bread or other food into water to attract fish.

9.11.6 Chumming

Chumming is defined as throwing food into water to attract fish. This practice is frequently applied in the waterways of northwestern Bosnia. Chumming should become illegal because it allows anglers to have much greater fishing success and thus puts great pressure on fish populations.

9.11.7 Bait Fishing

Fishing with bait should not be practiced because it significantly contributes to the mortality of fish. Fish often swallow the hook deeply. When the hook is removed, it causes injuries to the fish that may result in death. If fish escape, they often die. In a case study done on trout, 25% of those that were caught on bait died when released compared, to 4% that were caught on flies and other lures (Alberta Environmental Protection, 1998).

9.11.8 Releasing Fish

Releasing fish is a very important component of successful fisheries management. Fish caught below legal size or after the daily limit, need to be released. All fish need to be released immediately after they are caught. If fish are released immediately and handled gently with care, they have an excellent chance of survival (Alberta Environmental Protection, 1998).

9.11.9 Tips on Releasing Fish

- Retrieve the fish quickly
- Handle the fish gently and carefully
- Remove the hook gently and carefully
- Do not squeeze the fish
- Keep fingers away from the gills
- Release the fish as soon as possible
- Keep the fish in water as much as possible

- Deeply swallowed hooks should be inside the fish
- Revive the fish by holding it in water (facing the current) until it swims away (Alberta Environmental Protection, 1998).

9.11.10 Culling

Holding live fish and culling them according to size should be illegal. Fish that are being held on a stringer or in a tub often die when released because they have experienced high levels of stress and sustained injuries to their scales, gills and fins (Alberta Environmental Protection, 1998).

9.12 Further Recommendations for Better Fisheries Management

The monitoring of angling activity does not have to be done solely by the professional FEOs. Formation of ad hoc patrols by influential members of the OSF could also improve monitoring.

Organize meetings with members of the local police and other organs of local law enforcement, along with water quality inspectors. Meetings may act as forums for discussion where numerous problems relating to fisheries management can be addressed and discussed among those present.

Meetings with representatives of companies that release polluted water into the waterways are suggested to establish a synchronized action plan in case pollution is found to harm fish.

Frequent meetings are suggested between the executive members of OSF, FEOs and watch patrols (influential members of OSF). At these meetings, information and ideas can be shared. Mistakes can be identified and corrected in the future. All of these meetings should be based on a continuous improvement model for fisheries management.

The FEOs and members of the OSF responsible for monitoring the waterways need to levy fines on those who do not obey fishing regulations. The monetary value of fines needs to be substantial. Low fines allow some fishermen to keep on breaking the law, because they can offset the price of fines by catching more fish which they sell at the

market (Pasalic 1997, pers. comm.). Records of fines need to be kept. Fines need to be passed on to the courts and their realization also needs to be monitored. Establishment of a good working relationship between the OSF and the courts is essential to have speedy convictions realized. The municipality of Bosanska Krupa had only one full-time FEO working before the war (Pasalic 1997, pers. comm.). In order to have successful fisheries management, the municipality should have three full-time FEOs who work throughout the year (Institute for Biology at the University of Sarajevo, 1984). The OSF should hire FEOs who will be strict in enforcing the fishing regulations. The FEOs should be chosen for their ability to remain apart from local connections and social pressures. Perhaps, hiring someone from outside of the town of Bosanska Krupa may be a solution. In the town, most of the people know one another and may worry about their social status when levying fines on those who break fishing regulations.

Besides monitoring fishing activities, the monitoring of industrial or other activities that negatively affect waterways is required. Stocking of waterways with fry is also a responsibility of OSF. Stocking should not alter the existing aquatic ecosystem, allow disease to be introduced, allow introduction of non-native species of fish, or allow fish with poor health to be introduced.

Waterways are assigned to the local OSF for purposes of fisheries management in Bosnia (Institute for Biology at the University of Sarajevo, 1984). Protection of the "water commons" needs to be in the interest of all citizens of the municipality of Bosanska Krupa. Monitoring of pollution, especially at locations where it enters a waterway, should be the responsibility of the FEOs, other members of the OSF, police, pollution inspectors and other citizens who are interested in environmental protection.

CHAPTER 10: OTHER IMPORTANT ISSUES

10.1 Hydroelectric Powerplants in Una-Sana Canton

The Una-Sana Canton does not have enough electricity-producing facilities (i.e. thermoelectric and hydroelectric powerplants) to fulfill its own electricity needs. Before the war it received electricity from thermoelectric powerplants in northcentral Bosnia and Croatia. The transmission lines that connect Una-Sana Canton with the Cantons of Tuzla-Podrinje and Zenica-Doboj pass through Serb and Croatian territories (see Figure 1.2). During the war, the transmission lines were cut off by the armies and no electricity was allowed to reach Una-Sana Canton. The only source of electricity during the war in the Una-Sana Canton was from the sole hydro-electric powerplant in Kostela, near Bihac, with capacity of 1.2 – 6 Mw. It used to supply electricity to hospitals, surgeries, schools and some production facilities (University of Sarajevo – Faculty Institute of Economics, 1997). At the end of the war, the Serbs and the Croats restored the transmission lines and allowed the electricity to pass through their territory (Bahtijaragic 1998, pers. comm.). Many people in Una-Sana feel that the Serbs and the Croats can always cut the supply of power to the Canton, and therefore would like to be self-sufficient in electricity. Una-Sana Canton has tremendous hydroelectric potential and some people in the government would like to see the building of hydroelectric powerplants on the River Una and its tributaries over the entire Una-Sana Canton (Marjanovic 1997, pers. comm.). There are plans to build hydroelectric powerplants on the Sana River (tributary of the River Una) near Vrhpolja. These powerplants would be smaller than 30 GWh. There is also one hydroelectric powerplant planned near Martin Brod, but no final decisions have been made (Bahtijaragic 1998, pers. comm.).

10.1.1 Negative Effects of Hydroelectric Powerplants

Hydroelectric powerplants alter the dynamics and rates of water flow. This in turn may result in the washing-off and destruction of spawning areas for fish. Alteration of water dynamics and rates of flow may scar the river bed and the banks, damaging the overall

aquatic environment. Hydroelectric dams are physical barriers to fish. In some cases dams may not allow fish access spawning areas, resulting in local extinction. Hydroelectric dams require upstream flooding, which often infringes on agricultural areas for local farmers. Furthermore, the ecosystem of the flooded area becomes altered. Over time, siltation occurs in reservoirs. This reduces storage capacity and affects the operation of powerplant. Significant changes in water temperature may result because of turbine friction and storage time in the reservoir. Turbines are deadly traps for fish, especially during migration. The construction of hydroelectric powerplants would have adverse environmental effects especially for salmonids (i.e. grayling, trout and Danube salmon) because these fish require free access to their spawning areas in rapidly moving water.

10.1.2 Collaboration Against Development of Hydroelectric Powerplants

In order to have productive and diverse future fisheries in the waterways of Una-Sana Canton, development of hydroelectric powerplants should not be allowed. Environmental NGOs such as "Zeleni" in Bosanska Krupa and "Unski smaragdi" in Bihac, along with OSF and other stakeholders who have an interests in protecting the fisheries (such as tourism), should join hands and oppose the development of hydroelectric powerplants in Una-Sana Canton, or, at the least, require very careful mitigative design (e.g. effective fish ladders and operating schedules).

10.2 A Responsible Approach to Fresh-Water Stock Enhancement

To ensure success and avoid repeating mistakes, we must take a responsible approach to developing, evaluating and managing fresh-water stock enhancement programs. A responsible-approach concept with several key components is described below. Each component is considered essential to optimize enhancement:

- prioritize and select target species for enhancement
- develop a species management plan that identifies harvest opportunity, stock rebuilding goals, and genetic objectives
- define quantitative measures of success
- use genetic resource management to avoid deleterious genetic effects
- use disease and health management
- consider ecological, biological and life-history patterns when forming enhancement objectives and tactics
- identify released hatchery fish and assess stocking policy guidelines
- use adaptive management

  (Leber, 1995).

The proposed aquaculture facility in the Municipality of Bosanska Krupa needs to do exactly this. It is important to realize that the project is not finished when it is built. The evaluation of all the above points is required on a continuous basis over time, followed by appropriate intervention. Implementing these components into the municipal aquaculture facility would mean an improvement to its fresh-water enhancement plan.

10.3 References as a Guide

The references and personal communications cited in this project will be useful to the sustainable development agency/organization when the proposed project is considered for approval.

10.4 Audience

The recommendations of this study are addressed to stakeholders interested in sustainable development projects, particularly in the field of fisheries (with special emphasis on grayling). The recommendations are addressed particularly to international aid agencies operating in northwestern Bosnia (e.g. FAO, UNDP, UNOPS, USAid, etc.). Foreign fishing organizations with strong financial portfolios (e.g. fishing organizations from

Slovenia, Italy and Austria) may be interested in investing in the proposed project. These foreign fishing organizations could form some kind of affiliation with the OSF from Bosanska Krupa, where foreign investment in a proposed fisheries project would allow them to come to the municipality for fishing excursions. The recommendations are especially important for the local OSF, the municipal government (including the MDC and the TU), as well as the two Ministries of the Una-Sana Canton to whom the proposed project is of direct relevance (i.e. the Ministry for Agriculture, Forestry and Water Resources and the Ministry for Regional Planning, Environment and Reconstruction). The recommendations presented in this project are also intended for the general public (i.e. all interested citizens of the Municipality of Bosanska Krupa).

CHAPTER 11: SUMMARY

In northwestern Bosnia and Herzegovina there was widespread overharvesting of the fisheries resources before the outbreak of war in 1992. Close to four years of war in the country put even greater pressure on the fisheries, mainly due to a lack of food and general lawlessness. In the post-war period, the practice of overharvesting continued, resulting in an extraordinary decline in fish populations. This project addresses factors that have contributed to the degradation of the fisheries resources in the rivers of the Municipality of Bosanska Krupa. The project proposes that a fish hatchery for European Grayling (*Thymallus thymallus*) be developed as a sustainable development pilot project for the Municipality on the River Krusnica.

The goal of this project is to develop a sustainable development project that can be carried out in northwestern Bosnia. When implemented, it would help the local residents of the Municipality of Bosanska Krupa recover from the ravages of close to four years of war. The project would also contribute to a sustainable development strategy for the Una-Sana Canton and the nation as a whole.

The objectives include:

- to address factors that have contributed to the degradation of fisheries resources in the rivers of the Municipality of Bosanska Krupa
- to propose a grayling (*Thymallus thymallus*) hatchery on the River Krusnica as a sustainable development project for the Municipality of Bosanska Krupa
- to address possible means to achieve sustainable fisheries management in the Municipality of Bosanska Krupa.

It is important to understand that development of a grayling (*Thymallus thymallus*) hatchery on its own will not solve the problem of fisheries situation in the waterways of the Municipality of Bosanska Krupa. The proposed aquaculture facility is only one part of the overall remedy for fisheries in the municipality. The initial role of the proposed hatchery (i.e. the first four years) should focus in rehabilitation of the fish-stocks in the

municipal waterways. As the number of fish increases, hatchery should shift its production focus to the market place (i.e. selling the fry to other municipalities for stocking and selling larger fish to consumer for food). Operation of aquaculture facility needs to be in accordance with improvements in fisheries management plan that consists of Habitat Maintenance, Fish Conservation, Fish-Use Allocation, Education, Enforcement, Inventory, Monitoring and Research, and Improvements in Sport Fishing Regulations. Only then we can expect to see improvements in the fisheries resources of the Municipality of Bosanska Krupa.

REFERENCES

Alberta Environmental Protection. 1998. Alberta Guide to Sportfishing Regulations. Sports Scene Publications Inc. Edmonton, Alberta.

Ali, Syed Sabir. 1993. An Introduction to Freshwater Fishery Biology. University Grants Commission H-9. Islamabad, Pakistan.

Alt, Kenneth T. 1980. "Inventory and cataloging of sport fish and sport fish waters of western Alaska". Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(G-I-P):32-59. Juneau, Alaska, USA.

Armstrong, Robert H. December 1986. "A Review of Arctic Grayling Studies in Alaska 1952-1982". Biological Papers of the University of Alaska. Institute of Arctic Biology. Number 23. Fairbanks, Alaska, USA.

Berry, David K. April 1998. Alberta's Arctic Grayling Management and Recovery Plan. Alberta Environmental Protection. Natural Resources Service. Fisheries Management Division. Edmonton, Alberta.

Brown C. and Buck, C. Jr. 1939. "When do trout and grayling fry begin to take food?" Journal of Wildlife Management. 3(2):134-140.

Brundtland, Gro Harlem et. al. 1987. Our Common Future. Oxford University Press. New York, USA.

Carlstein, Mikael. 1993. "Natural food and artificial, dry starter diets: effects on growth and survival in intensively reared European grayling". Aquaculture International. Vol. 1. 112-123 pp.

Colombo, John Robert. 1997. 1997 Canadian Global Almanac. Macmillan Canada. Toronto, Canada.

Corbin, John S. and Young, Leonard G. 1997. "Planning, Regulation, and Administration of Sustainable Aquaculture". Sustainable Aquaculture, Edited by John E. Bardach. 201-234 pp. John Wiley & Sons, Inc. New York, USA.

Daly, Herman E. 1996. Beyond Growth. Beacon Press. Boston, USA.

Davidovic, Rade. 1977. "Pecina Suvaja". Review of Research of Science - University of Novi Sad, Volume 7. 271-276 pp. Novi Sad, Yugoslavia.

de Bruyn, M. and P. McCart. 1974. "Life history of the grayling (*Thymallus arcticus*) in Beaufort Sea drainages in the Yukon Territory". In P. J. McCart, ed. Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon and Northwest Territories. Biological Report Series 15(2). 39 pp. Canadian Arctic Study, Ltd. Calgary, Alberta.

Defense Mapping Agency. 1996. Map of Bosanska Krupa, Bosnia and Herzegovina 2384 I M709 Edition 6-DMA (Scale 1:50,000). The United States Government. Washington D. C., USA.

Denitch, Bogdan. 1994. Ethnic Nationalism: The Tragic Death of Yugoslavia. University of Minnesota Press. Minnesota, USA.

Ecologist, The. 1993. Whose Common Future? New Society Publishers. Gabriola Island, British Columbia.

Ekonomski Fakultet Univerziteta u Sarajevu – Institut. 1996. Studija: "Strategija Razvoja Unsko-Sanskog Kantona". Institute for Economics at the University of Sarajevo. Sarajevo, Bosnia and Herzegovina. November.

Encyclopaedia Britannica. 1998. Britannica CD 98 Multimedia Edition. Encyclopaedia Britanica Inc. London, UK.

Finley, Christopher. 1998. Pipeline Project Cumulative Effects Assessments. Faculty of Environmental Design, Master's Degree Project. University of Calgary, Calgary, Alberta.

Fisheries Management Division. 1997. A Fish Conservation Strategy for Alberta. Alberta Environmental Protection, Natural Resources Service. Edmonton, Alberta.

Hardin, Garrett. December 13, 1968. "The Tragedy of the Commons". Science. Vol. 162.

Hygienic Institute in Bihac. 1984. Laboratory tests on Chemical and Physical Properties of Water in the River Krusnica. Bihac, Bosnia and Herzegovina.

Institute for Biology at the University of Sarajevo. August, 1984. Ribolovna Osnova za Ribolovno Podrucje "Una I". Udruzenje Sportskih Ribolovaca – Una I. Sarajevo, Bosnia and Herzegovina.

Jankovic, D. 1964. "Synopsis of biological data on European grayling (*Thymallus thymallus* (*Linnaeus*) (1758))". FAO Fish. Synop. No. 24, F16/S24 (Rev. 1). FAO: Rome, Italy.

Kumar, K. 1989. Conducting Key Informant Interviews in Developing Countries. A.I.D. Program Design and Evaluation Methodology report No. 13. Agency for International Development. Washington, D. C., USA.

Lakusic, Radomir. 1991. "Ekoloska diferencija prostora sliva Une i njegova vrijednost". Bilten 6, serija b - naucni skupovi i savjetovanja. Drustvo Ekologa Bosne i Hercegovine. Sarajevo, Bosnia and Herzegovina.

Law on Fundamentals of Local Self-Government. 1995. Sarajevo, Bosnia and Herzegovina. November.

Leber, Kenneth M. 1995. "A Responsible Approach to Marine Stock Enhancement". Uses and Effects of Cultured Fishes in Aquatic Ecosystems. American Fisheries Society Symposium 15:167-175 pp. Bethesda, Maryland, USA.

Locke, A. 1998. "Modeling the effects of poststocking survival rates on the success of stocking hatchery Atlantic salmon in a New Brunswick river". North American Journal of Fisheries Management. Vol. 18 (3).

Lovacko Drustvo "Grmec". 1990. Lovnoprivredna Osnova za Loviste "Grmec" Sanica. Kljuc, Bosnia and Herzegovina. November.

MAC. August 1997. Mine Activities Report. United Nations Mine Action Centre. Bihac, Bosnia and Herzegovina.

Marjanovic, Bosko, Ibrahim Dupanovic, Milan Miljus, Hasan Zulic, Mira Ljubijankic, Vilim Mazar, Adem Boric, Zvonko Franjic and Ilija Dosenovic. May 1986. Unski smaragdi '86. Drustvo za Stvaranje Kulture Cuvanja i zastite rijeke Une "Unski smaragdi". Bihac, Bosnia and Herzegovina.

Markovic, Ante, Ejub Sijercic and Asim Abdurahmanovic. 1991. Etnicka Karta Bosne i Hercegovine. Altermedia. Sarajevo, Bosnia and Herzegovina.

Marsh, James H. The Canadian Encyclopedia, Vol. I, A-For. Hurtig Publishers Ltd. Edmonton, Alberta.

Military Survey. 1996. Map of Bosanska Krupa (Krupa na Uni) M903 1-GSGS (Scale 1:10,000). Crown. Ministry of Defence. London, United Kingdom.

Mogus, Milan, Josip Voncina, Karla Cizelj, Vladimir Ivir, Colleen Ridjanovic, Midhat Ridjanovic and Marijan Urbany. 1981. Djepni Rjecnik: Hrvatskosrpsko-engleski (Dio II). Mladost. Zagreb, Croatia.

Muus, Bent J. and Dehlstrom, Preben. 1978. Collins Guide to the Freshwater Fishes of Britain and Europe. Wm. Collins Sons and Co. Ltd. London, United Kingdom.

Nelson, P. H. 1954. "Life history and management of the American grayling (*Thymallus signifer tricolor*) in Montana". Journal of Wildlife Management. 18: 324-342.

Neuman, W. 1994. Social Research Methods: Qualitative and Quantitative Approaches. Allyn and Bacon. Needham Heights, Massachusetts, USA.

Northcote, Thomas G. 1995. "Comparative biology and management of Arctic and European grayling (*Salmonidae, Thymallus*)". Reviews in Fish Biology and Fisheries. Vol 5, pg. 141-194.

O'Connor, Richard. 1989. "From Fertility to Order". Culture and Environment in Thailand. Siam Society. Bangkok, Thailand.

Ocvirk, J. and Vovk, J. 1986. "The role of live zooplankton in the artificial rearing of the grayling (*Thymallus thymallus L.*)". Ichtyos. Vol. 3, 8-12 pp.

Pratt, B. and Loizos, P. 1992. Choosing Research Methods. Oxfam. Oxford, United Kingdom.

PROGRESS and IMG. 1996. Map of Cantons and Regions in Bosnia and Herzegovina. Mapinfo database at the UNDP/UNOPS Bihac, Bosnia and Herzegovina.

PROGRESS and IMG. 1996. Map of Population Density in 1991 of the Municipality of Bosanska Krupa. Mapinfo database at the UNDP/UNOPS Bihac, Bosnia and Herzegovina.

PROGRESS Bosnia & Herzegovina. 1996. AIDE-MEMOIRE. Programme for Rehabilitation and Sustainable Socio-Economic Development in Bosnia & Herzegovina. UNDP/UNOPS Project: B&H/96/025. Sarajevo, Bosnia and Herzegovina. August.

PROGRESS-BiH-A. 1997. Project Document: Rehabilitation of the Health Station in the Municipality of Bosanska Krupa. UNDP/UNOPS Project: B&H/96/025. Bihac, Bosnia and Herzegovina. October.

PROGRESS-BiH-B. 1997. Tool CMB 2: The Municipal Development Committee: Establishment, Evolution and Perspective. UNDP/UNOPS Project: B&H/96/025. Sarajevo, Bosnia and Herzegovina. June.

PROGRESS-BiH-C. 1997. Tool CMB 4: Definition, Composition, Objectives and Functions of the Technical Unit. UNDP/UNOPS Project: B&H/96/025. Sarajevo, Bosnia and Herzegovina. June.

Redzic, Sulejman et. al. 1991. "Ljekovite biljke u nekim ekosistemima doline rijeke Une". Bilten 6, serija b - naucni skupovi i savjetovanja. Drustvo Ekologa Bosne i Hercegovine. Sarajevo, Bosnia and Herzegovina.

Reed, R. 1964. "Life history of migration patterns of Arctic grayling, *Thymallus arcticus* (Pallas), in the Tanana River drainage of Alaska". Alaska Department of Fish and Game Research Report No. 2. Juneau, Alaska, USA.

Ritz, Josip. 1973. Englesko Hrvatski - Hrvatski Engleski Poljoprivredni Rjecnik. Liber: Zagrebacko Sveuciliste, Zagreb, Croatia.

Roguski, E. A. 1967. "Inventory and cataloging of the sport fish and sport fish waters in the interior of Alaska". Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1966-1967. Project F-5-R-8, 8(16-B):231-246 pp. Juneau, Alaska, USA.

Roguski, E. A. and Winslow, P. 1969. "Investigations of the Tanana River and Tangle Lakes grayling fisheries: Migratory and population study". Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1968-1969. Project F-9-1, 10(16-B):333-351pp. Juneau, Alaska, USA.

Robson, Colin. 1993. Real World Research. Blackwell Publishers Inc. Malden, Massachusetts, USA.

Selimovic, Muharem. 1991. "Ribar, Riba i Ribarska Osnova o Uni". Bilten 6, serija b - naucni skupovi i savjetovanja. Drustvo Ekologa Bosne i Hercegovine. Sarajevo, Bosnia and Herzegovina.

Solaja, M. and Pocrnjic, Z. 1991. "Problemi ocuvanja populacije covjecije ribice (Proteus anguinus) u podzemnim vodama Grmeca". Bilten 6, serija b - naucni skupovi i savjetovanja. Drustvo Ekologa Bosne i Hercegovine. Sarajevo, Bosnia and Herzegovina.

Sorgeloos, P. 1973. "High density culturing of the Brine shrimp, *Artemia salina*." Aquaculture. Vol. 1, 385-391 pp.

Strahler, Arthur Newell. 1981. Physical Geology. Harper & Row, Publishers. New York, USA.

Tack, S. L. 1971. "Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage". Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971. Project F-9-3, 12(R-I). Juneau, Alaska, USA.

Tack, S. L. 1973. "Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage". Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973. Project F-9-5, 14(R-I). Juneau, Alaska, USA.

Tack, S. L. 1974. "Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage". Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1973-1974. Project F-9-6, 15(R-I). Juneau, Alaska, USA.

Tack, S. L. 1980. "Migrations and distribution of Arctic grayling in interior and arctic Alaska". Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(R-I). Juneau, Alaska, USA.

Tehnicka Jedinica. 1997. Turisticka brosura Bosanske Krupe. Opstina Bosanske Krupe. Bosanska Krupa, Bosnia and Herzegovina.

Teramoto, K. and Kinoshita, S. 1961. "Some informations on the culture of *Artemia*". Bull. Jap. Soc. sci. Fish. 27 (8), 801-804 pp.

Tremblay, M. 1982. "The key informant technique: A non-ethnographic application". In Robert G. Burgess (ed.), Field Research: A Sourcebook and Field Manual. Alan & Unwin. London, United Kingdom.

UNHCR. 1996. "Bosnian Refugees Doors Slam". The Economist. September 28, 1996. Pg. 63-64. June.

United Nations. January 1997. Permanent Missions to the United Nations - No. 278. Protocol and Liaison Service, Room S-201, United Nations, New York, USA.

University of Sarajevo - Faculty Institute of Economics. 1997. Development Strategy and Description of the Public Structures of the Una-Sana Canton. Sarajevo, Bosnia and Herzegovina.

Unknown. 1981. Map of the Former Yugoslavia. Maps & Airphotos Collection at the University of Calgary. Calgary, Alberta.

Watling, H. and Brown, C. J. D. 1955. "The embryological development of the American grayling (*Thymallus signifer tricolor*) from fertilization to hatching". Transactions of the American Microscopical Society 74(1):85-93.

Yin, R. 1989. Case Study Research: Design and Methods. Sage Publications, Inc. Newbury Park, California, USA.

KEY INFORMANTS AND PERSONAL COMMUNICATIONS

Ajanovic, Omer. January 1998. Personal Communication with Charge de Affaires of the Embassy of Bosnia and Herzegovina in Islamabad. Islamabad, Pakistan.

Bahtijaragic, Iris. May 1997 – December 1998. Personal Communication with Programme Officer for UNOPS – Bihac. Bihac, Bosnia and Herzegovina.

Brankovic, Seid. April 1998. Personal Communication via e-mail. Sustainable Development Expert in Bosnia and Herzegovina.

Civilna Zastita. November 1997. Personal Communication with members of the Municipal Civil Defense Department. Bosanska Krupa, Bosnia and Herzegovina.

Cluckers, Anne Marie. 1997. "Workshop on UNOPS' Strategy in Bosanska Krajina". Personal Communication by UNOPS Programme Coordinator. Hotel "Sedra", Bihac. June 23rd.

Clipperton, Kasey. December 1998. Personal Communication with In-Stream Flow Needs Biologist. Alberta Environmental Protection. Cochrane, Alberta.

Grieef, Patricia. October 1998. Personal Communication with Graduate Student at the Faculty of Environmental Design who is working on the project titled Design Recommendations and School Programming for a Wetland Area at the Sam Livingston Fish Hatchery. Calgary, Alberta.

Hamor, Thomas. August - December 1998. Personal Communication. Fish Production Biologist at Sam Livingston Fish Hatchery, Alberta Environmental Protection. Calgary, Alberta.

Harbas, Fikret. 1997 – 1998. Personal Communication and Communication via e-mail. Member of the Technical Unit at the Municipality of Bosanska Krupa. Bosanska Krupa, Bosnia and Herzegovina.

Harbas, Hikmet. 1997. Personal Communication. Executive member of both the Organization for Sport Fishermen and the Organization for War Invalids in Bosanska Krupa. Bosanska Krupa, Bosnia and Herzegovina.

Kannan, Jean-Selim. June – November 1997. Personal Communication with Project Manager of UNOPS in Bihac. Bihac, Bosnia and Herzegovina.

Komic, Esad. July 1997. Personal Communication with the President of "Zeleni" - Environmental NGO in the Municipality of Bosanska Krupa. Bosanska Krupa, Bosnia and Herzegovina.

Marjanovic, Bosko. June – November 1997. Personal Communication with the former president of the largest environmental NGO (i.e. "Unski smaragdi") in Una-Sana Canton. Bihac, Bosnia and Herzegovina.

Monita, Darwin. November 1998. Personal Communication with Fish Biologist at Greenview Aqua-Farm Ltd. Calgary, Alberta.

Pasalic, Hasan. October – December 1998. Personal Communication with an experienced Angler and the Native of Bosanska Krupa who presently lives in Calgary. Calgary, Alberta.

Redzic, Sanda. November 1997. Personal Communication with the head of Tourism Department at the Municipality of Bosanska Krupa. Bosanska Krupa, Bosnia and Herzegovina.

Retarie, Alan. July 1997. Personal Communication with UNOPS' Technical Advisor. Sarajevo and Bihac, Bosnia and Herzegovina.

Saric, Hasim. 1997. Professional Photographer in Bosanska Krupa. Photo courtesy. Bosanska Krupa, Bosnia and Herzegovina.

Sehic, Sead. November 1997. Personal Communication with the president of hunting organization "Divojarac". Bosanska Krupa, Bosnia and Herzegovina.

Sertovic, Adem. November, 1997. Economist and the member of TU in the Municipality of Bosanska Krupa. Personal Communication. Bosanska Krupa, Bosnia and Herzegovina.

Sertovic, Mediha. November, 1997. Director of Center for Social Work. Personal Communication. Bosanska Krupa, Bosnia and Herzegovina.

Appendix A: MDC Members in Bosanska Krupa

1. SUAD MESIC	MAYOR OF THE MUNICIPALITY
2. HAJRUDIN KRUPIC	CHIEF OF SECTOR FOR ECONOMY
3. MUMIN VELADZIC	CHIEF OF SECTOR FOR AGRICULTURE
4. ENES MUSTADANAGIC	DIRECTOR OF THE VETERINARY STATION
5. SEFKET GOLETIC	PROFESSIONAL CO-OPERATOR FOR INDUSTRY ENERGY AND MINING
6. MEHIDA SERTOVIC (W)	DIRECTOR OF CENTER FOR SOCIAL WORK
7. NAILA KOMIC (W)	PROFESSIONAL CO-OPERATOR IN CENTER FOR RECONSTRUCTION AND DEVELOPMENT
8. HASAN ORASCANIN	DIRECTOR OF GYMNASIUM
9. SENAD VELAGIC	SECRETARY OF WAR INVALIDS ASSOCIATION
10. ESAD CRNKIC	PRIVATE ENTREPRENEUR
11. DJELDINA KURTOVIC (W)	ASSOCIATION OF FAMILIES OF KILLED SOLDIERS
12. MUSTAFA RAMIC	DIRECTOR OF HOSPITAL
13. SULJO HALKIC	AGENCY FOR HUMANITARIAN AID
14. MUHAREM PASALIC	HEAD OF WAR INVALIDS ASSOCIATION
15. ELVIR KULENOVIC	CHIEF OF DEVELOPMENT IN SIP "UNA"
16. MUHAMED ORASCANIN	TRAFFIC COMPANY "KRUPATRANS"
17. SEFIK EMRIC	REPRESENTATIVE OF PISTALINE DISTRICT
18. BEKIR VELIC	REPRESENTATIVE OF JEZERSKI DISTRICT
19. MIROSLAV VUCICEVIC	TEACHER
20. BAJRO KURTOVIC	REPRESENTATIVE OF ARAPUSA DISTRICT
21. MIRJANA ALEKSIC (W)	ENGINEER IN THE MUNICIPALITY
22. MEHMED MUSTEDANAGIC	REPRESENTATIVE OF THE ASSOCIATION OF RETIRED PEOPLE
23. MERIMA ELJAZOVIC (W)	DIRECTOR OF AGENCY FOR HUMANITARIAN AID
24. MIRSAD SULJIC	POLICEMAN
25. BEDITA KURPOVIC (W)	ECONOMIST IN THE MUNICIPALITY

(W) = WOMAN

Appendix B: TU Members in Bosanska Krupa

1. ADEM SERTOVIC - ECONOMIST
2. FIKRET HARBAS - INDUSTRIAL DESIGNER
3. SAMIR HAJDAREVIC - CIVIL ENGINEER

Appendix C: Wild Birds and Animals that are Hunted in the Municipality of Bosanska Krupa

Family - *Corvidae*

Raven (*Corvus corax*)
Grey Crow (*Corvus corone cornix*)
Meg Pie (*Pica Pica*)

Family - *Anatidae*

Wild Duck (*Anas platyrhynchs*)

Family - *Falcomidae*

Hawk (*Accipiter gentilis*)
Kite (*Accipiter nisus*)
Eagle (*Aguila shrysaetus*)

Family - *Columbidae*

Wild pigeon (*Columba palumbus*)

Family - *Strigidae*

Forest Owl (*Bubo bubo*)

Family - *Tetraonidae*

Grouse (*Tetrao urogallus*)
Black Cock (*Tetrastes bonasia*)

Family - *Leporidae*

Wild Rabbit (*Lepus europaeus*)

Family - *Sciuridae*

Squirrel (*Sciurus vulgaris*)

Family - *Mustelidae*

Golden Marten (*Martes martes*)
White Marten (*Nartes foina*)
Big Weasel (*Mustela erminea*)
Badger (*Meles meles*)

Family - *Ursidae*

Brown Bear (*Ursus arctos*)

Family - *Canidae*

Gray Wolf (*Canis lupus*)
Red Fox (*Vulpes vulpes*)

Family - *Felidae*

Wild Cat (*Felis silvestris*)

Family - *Cervidae*

Deer (*Capreolus capreolus*)

Family - *Suidae*

Wild Boar (*Sus scrofa*)

(Ritz, 1973; Mogus, *et. al.*, 1981; Lovacko Drustvo "Grmec", 1990).