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THE INFLUENCE OF WATER AVAILABILITY ON THE HISTORICAL, DEMOGRAPHIC AND ECONOMIC DEVELOPMENT OF THE KVARNER ISLANDS (CROATIA)

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ABSTRACT

The general development of the Kvarner Islands has been closely connected to water resources. Unlike most of the Croatian archipelago, the Kvarner Islands posses a relatively well developed surface hydrology due to their unique climatic and geological features. The abundance of water assured the early development of a versatile economy. Up to the end of the Second World War, the economy was dominated by agriculture, while after the war tourism took over the leading role. The onset of mass tourism in the 1960's and 1970's could not have been possible without an appropriate water supply system which was developed simultaneously with the economic growth. Today, the Kvarner Islands are one of the best known tourist regions in Croatia, especially popular among German, Slovenian and Italian tourists. It should be pointed out that there is a huge discrepancy in the development of the large and small inhabited Kvarner Islands. Such a discrepancy is caused solely by the lack of water resources on the small islands, which in turn has a deep economic as well as demographic impact on those islands.

Key words: islands, water, economy, tourism, Kvarner, Croatia

L'INFLUENZA DELLA DISPONIBILITÀ IDRICA SULLO SVILUPPO STORICO, DEMOGRAFICO ED ECONOMICO DELLE ISOLE DEL QUARNARO (CROAZIA)

SINTESI

Lo sviluppo generale delle isole del Quarnaro è stato sempre strettamente collegato alle risorse idriche. A differenza della gran parte dell'arcipelago croato, le isole del Quarnaro possiedono un'idrografia di superficie abbastanza sviluppata grazie alle loro caratteristiche climatiche e configurazioni geologiche singolari. L'abbondanza dell'acqua ha assicurato un progresso veloce ad un'economia versatile, fino alla fine della seconda guerra mondiale dominata dal settore agricolo, poi dal turismo. L'inizio del turismo di massa negli anni Sessanta e Settanta del secolo scorso non sarebbe stato possibile senza un sistema di rifornimento d'acqua adeguato che si andò sviluppando contemporaneamente con la crescita economica. Oggi, le isole del Quarnaro sono una delle regioni turistiche più conosciute in Croazia, particolarmente gradite ai turisti tedeschi, sloveni e italiani. Va sottolineato che dal punto di vista dello sviluppo esiste una differenza sostanziale tra le isole del Quarnaro maggiormente estese, e quindi con un numero di abitanti più elevato, e quelle più piccole. Il divario è dovuto esclusivamente alla mancanza di risorse idriche nelle isole piccole, aspetto che a sua volta esercita un profondo impatto economico nonché demografico sulle stesse.

Parole chiave: isole, acqua, economia, turismo, Quarnaro, Croazia

INTRODUCTION

The Croatian archipelago consists of 1,246 islands, islets and rocks with a total area of 3,259.57 km^2 (Duplančić Leder et al., 2004), and a population of 119,605 according to the 2001 census (Statistical Yearbook, 2003). It is an area of unique historic, economic, and cultural development deriving from the specific geographical position and various natural characteristics such as its geology, geomorphology, climate, hydrology, vegetation, etc. Those elements enabled an early settlement, particularly of the larger islands,[1] and the establishment of a distinctive island society and economy somewhat different from that of the mainland. Size, position, and natural resources dictated the intensity and pace of the islands' economic progress. Generally, larger islands, especially those closer to the mainland, experienced a faster economic development, while smaller and more distant islands lingered behind.

The Kvarner Islands are located in the northernmost Croatian archipelago with the exception of the small uninhabited islands off the west coast of Istria (Fig. 1). Due to such a position, the Kvarner Islands have a specific climate and hydrology in comparison to the rest of the Croatian islands. Also, a geographical position close to Central Europe determined their specific social and economic development characterized by the early appearance of tourism as a significant factor in the islands' economy.

Demographic processes on the Kvarner Islands through a historical perspective were discussed by Lajić (2006), while Podgorelec (1999) explored the influence of migration on demographic processes on the Kvarner Islands. Bonacci (1993; 1995), Ožanić, Rubinić (1995) and Rubinić, Ožanić (1998) dealt with particular hydrological problems on Cres and Krk, and the most comprehensive study on hydrology and hydrogeology of the Croatian islands, including Kvarner Island, was done by Terzić (2006). Mesić (2004) analyzed the anthropogenic influence on the geochemical properties of the Vransko Jezero Lake, the most important water source on the Kvarner Islands. Lončarić (2010) systematically analyses the development of an insular society in the frame of water availability throughout history, the latest demographic and economic changes caused by growing tourism and the possible responses of the water supply systems to those changes.

This study was mainly based on the analysis of demographic and economic data from the Croatian Bureau of Statistics and from various published and non-published data of the local municipal services of the Kvarner Islands. The most useful information was obtained through personal communication with local authorities and through field work.

GEOGRAPHICAL SETTINGS

The Kvarner archipelago consists of 40 islands, islets and rocks with a total area of 1,044.27 km^2 and a population of 38,422 according to the 2001 census (Statistical Yearbook, 2003). Compared to some other groups of islands (e.g. the North Dalmatian archipelago with over 500 islands, islet and rocks) the Kvarner Archipelago is more homogenous, containing the two largest Croatian islands. Details about the area and the population of the inhabited Kvarner Islands are given in Table 1.

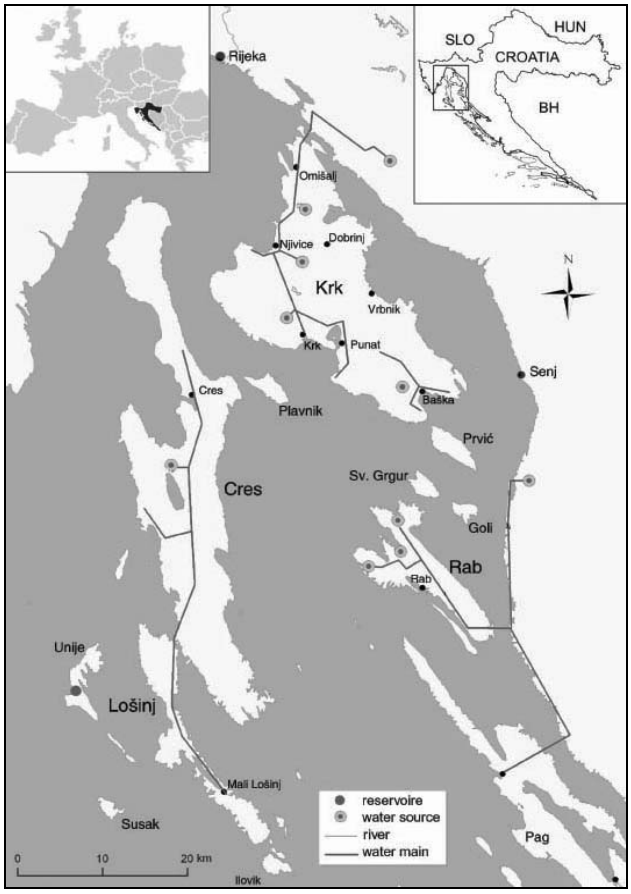

Fig. 1: Geographical position of Kvarner Islands and their water supply system.
Sl. 1: Geografski položaj kvarnerskih otokov in njihovega sistema za oskrbo z vodo.

1 According to Beller (King, 1993; Royle, 2001) small islands have an area smaller than 10,000 km^2, and a population under 500,000. But, in terms of such definition, even the two largest Croatian islands, Cres and Krk, would be well under the size of a large island. Therefore, King (1993) questions such a definition, regarding it inappropriate for the smaller Mediterranean archipelagos. According to Magaš (1996; 1998) small Croatian islands are those with three settlements or less.

Table 1: Area and population of the inhabited Kvarner Islands.
Tabela 1: Površina in prebivalstvo naseljenih kvarnerskih otokov.

	Island	Area* (km^2)	Population**
LARGE	Cres	405.70	2,959
	Krk	405.21	17,860
	Rab	86.11	9,476
	Lošinj	74.36	7,775
SMALL	Unije	16.87	90
	Ilovik	5.50	104
	Susak	3.77	188
	Vele Srakane	1.18	8
	Male Srakane	0.60	2

* according to Duplančić Leder et al. (2004).
** 2001 census (Statistical Yearbook, 2003).

Geologically, the Kvarner Islands are characterized by the prevalence of carbonate rocks, from Lower Cretaceous limestone and dolomite to the foraminiferal limestone of the Eocene (Mamužić et al., 1973; Šušnjar et al., 1973; Hećimović, 2009; Marinčić, 2009; Vlahović, Velić, 2009). On the islands of Krk and Rab, there are significant areas of Eocene flysch, while quaternary sediments such as *terra rossa* can be found on most of the Kvarner Islands. Loess sediments cover most of the Susak Island and parts of Unije, Vele Srakane and Male Srakane Islands. Flysch, *terra rossa* and loess have an important role in the islands' economy being the areas most suitable for intensive agriculture.

The Kvarner Islands are in the border zone between a mediterranean (Csa type, according to Koppen), and submediteranean climate (Cfa) (Šegota, Filipčić, 2003). The Cfa type is prevalent while the Csa type is restricted to the southernmost parts of Lošinj Island, western parts of Rab Island, some smaller regions on Krk and Cres Islands and to Susak, Unije, Ilovik, Vele Srakane and Male Srakane islands. The key difference between the two climate types is the amount of rainfall in the driest month (July), which is ≤40 mm for the Csa type (Šegota, Filipčić, 2003). Generally, the Kvarner Islands have larger annual amounts of rainfall than the rest of the Croatian islands, ranging from 900 mm (Lošinj Island) to almost 1,500 mm (the highest parts of the Krk Island). Mean annual temperatures are around 15°C; January and February are the coldest, and July and August the warmest months, with temperatures of 6°C and 24°C, respectively (Stražičić, 1975; Šegota, Filipčić, 1996). Predominant winds are the *bora* – a mainly north-easterly wind with the highest occurrence in the winter months, and the *sirocco* – a south-easterly wind which occurs mostly during autumn and spring. The *bora* usually brings cold and dry weather, while the *sirocco* brings clouds and heavy rains. Both of the winds regularly reach gale force (Penzar et al., 2001). During the warm part of the year, sea-land breezes blow daily, easing the heat. Such a favourable climate was one of the important factors for tourism development which consequently affected the overall development of the islands.

HYDROLOGICAL CHARACTERISTICS OF THE KVARNER ISLANDS

Due to high precipitation combined with the occurrence of relatively impermeable sediments, the Kvarner Islands have a relatively well developed surface hydrology. Surface water appears in the form of lakes, permanent and periodical water courses, springs and pools. Vransko Jezero Lake on the Island of Cres is the largest permanent lake on the Croatian islands. It has an area of 5.5 km^2, with the volume of 220 million m^3 at the mean level, which makes it the largest reservoir of fresh water on the Croatian islands. The lake is a typical crypto depression; the mean level of the lake is 13.73 m above mean sea level (m.s.l.) while the bottom of the lake lies 61.5 m below sea level; the maximum depth of the lake is 74.4 m (Biondić et al, 1995). Water temperatures range from 4 °C during the winter to 25 °C during the summer. The average annual amplitude of the water level in the lake is 81 cm. The highest recorded water level was 295 cm above mean level in 1960, while the lowest level of 198 cm below mean level was recorded in 1938 (Ožanić, Rubinić, 1995). The lake has been intensively used in the water supply system of Cres and Lošinj Islands since the late 1950's, and the amounts of water pumped from the lake have been constantly increasing due to the growing demands of households and economy (tourism). The usage of lake water has had a substantial effect on the lake's water level, but the exact effects are a matter of debate among scientists. In the beginning of the 1990s, extensive research was conducted on the lake to understand its hydrographic mechanism and the rate of water exchange. Those studies were partially sparked by the abrupt drop of the water level of the lake from the 1985 to 1990. During that period, water level decreased at an annual rate of 48 cm (in contrast to 4.2 cm average annual decrease recorded in the period from 1929 to 1995). The causes for such a decrease were several unusually dry years combined with the raised consumption of water due to intense tourism development (Bonacci, 1995). Research also proved that the hydrological balance of the lake is very fragile and that the amounts of pumped water cannot be significantly increased without disturbing the lake's hydrological balance.

Krk Island is the second largest Kvarner Island with the most extensive surface hydrology. The island hosts two lakes and Vela Rika Creek, the only permanent wa-

tercourse on the Croatian islands. Ponikve Lake is an artificial lake situated in the central part of the island. It was formed in a karst depression 2.2 km long and 50 to 300 m wide built in carbonate rocks of the Upper and Lower Cretaceous, mostly limestones, limestone breccias and dolomites. The depression is covered with up to a 44 m thick layer of Quaternary sediments. During the period of intensive rains, a seasonal lake appears within the Ponikve depression, and disappears during the hot and dry summer months. Average annual precipitation is 1,255 mm while average annual evaporation is 1,043 mm and depression's catchment area covers around 33 km^2 (Rubinić, Ožanić, 1998). Water from springs in the Ponikve depression has been used in for supplying water since 1936. However, the growing population and economy required larger amounts of fresh water and in 1983 a 300 m long dam was built in the depression which separated the spring from ponors (swallow holes) preventing the drainage of surface water and creating an artificial lake. In 1987, a new longer dam was constructed enlarging the volume of the lake from 500,000 m^3 to 1.86 million m^3. In 2005, a new pump station began to operate with a theoretical capacity of 2,000 l/s. Today, about 2/3 of the water in the water supply system on Krk Island comes from Ponikve Lake (Lončarić, 2010). However, increased pumping during the summer months causes a rapid drop of the water level in the lake, as well as problems with water quality.

A lake near the town of Njivice is a crypto depression with lowest point at 7 m below m.s.l. while the mean water level is 1.5 m above m.s.l. The lake has a surface of 0.37 km^2 with volume of 1.5 million m^3 and a mean depth of 4.05 m. The lake is surrounded by a wide peat zone covered with thick vegetation (Rubinić, Ožanić, 1998). Because of the intensive eutrophication processes, the quality of the water is very low and it is primarily used as industrial water for a nearby chemical plant in the town of Omišalj.

Vela Rika Creek flows through the south-eastern part of the Krk Island. Its full length is 12 km, but the water flows throughout the year only in the upper part of the creek (Novosel - Žic, 1987). The catchment area encompasses surrounding limestone hills up to 550 m above m.s.l. During the heavy rains, the creek turns into a torrent with a maximum recorded flow of 130 l/s. When such events take place the creek regularly floods the coastal town of Baška (Lončarić, 2010).

On other Kvarner Islands the surface water appears only in the form of springs, pools, waterholes and periodical torrents. Numerous artificial and natural pools have been used in agriculture for watering crops and cattle but many of them have not been used for a long time and are now mostly overgrown with dense vegetation. Pools are often the only source of surface water on the small Kvarner Islands (Fig. 2).

Fig. 2: Artificial pool on the Island of Rab (photo: R. Lončarić).
Sl. 2: Umetni bazen na otoku Rab (foto: R. Lončarić).

Due to permeable carbonate rocks which are prevalent in the geological structures of the Kvarner Islands, most of the rain water rapidly infiltrates the underground where it is confined within aquifers. Those aquifers present substantial fresh water reservoirs on many Kvarner Islands, and play a vital role in the water supply, especially on smaller inhabited islands (Susak, Unije, Ilovik, Vele Srakane and Male Srakane). However, the quantity of the water in such aquifers is very limited and since the aquifers on the small islands lay close to the sea, there is always a risk of sea-water intrusion in case of excessive water pumping.

WATER SUPPLY ON THE KVARNER ISLANDS – PRESENT STATE

One of the basic preconditions for the Kvarner Islands' economic development was the establishment of the local waterworks systems. In the past, water consumption was extremely rationed since the main source of fresh water was the rain. Most of the water was used for agriculture, which meant that only small amounts were left for personal use. In the last few decades, the demand for water has been rapidly increasing with tourism and industry becoming the leading consumers of the fresh water. Since tourism is mostly limited to summer months, the consumption of water during the tourist season increases on some islands by six fold (Fig. 3) (Lončarić, 2010). Such an increase creates enormous pressure on the islands' aquifers and in extreme cases can cause water shortages. As a result, local authorities were forced to invest additional funds in upgrading the waterworks in order to secure regular water supply. Income from tourism enables the islands' communities to invest money in building and maintaining larger waterworks.

The water supply on the Kvarner Islands is somewhat different than on most of the other Croatian islands. Large bodies of water on some of the Kvarner Islands have enabled the development of waterworks which are not dependant on water from the mainland (Fig. 1). The Islands of Cres and Lošinj rely almost completely on water from the Vransko Jezero Lake, and the water supply on Krk is also based on local water sources. Additionally, Krk is connected to the mainland's waterworks as well, but that water is used only if the local sources fail to deliver enough water. Rab relies mostly on water from the mainland, but it also has local water sources which appear to be very useful during the peak of the tourist season.

In contrast to the large islands, the small inhabited Kvarner islands suffer constantly from water shortages. As previously mentioned, those islands have very limited local water sources and are not connected to the waterworks of large islands. Any further economic development of these islands is dependent on how quickly and how efficiently the problem of the water supply will be solved.

THE IMPACT OF WATER AVAILABILITY ON DEMOGRAPHICS AND ECONOMY

Demographic processes and water availability

Demographic trends on the Kvarner Islands have been closely connected to its economy. During times of economic rise, the population grew significantly, and during times of crisis, the islands' population rapidly de-

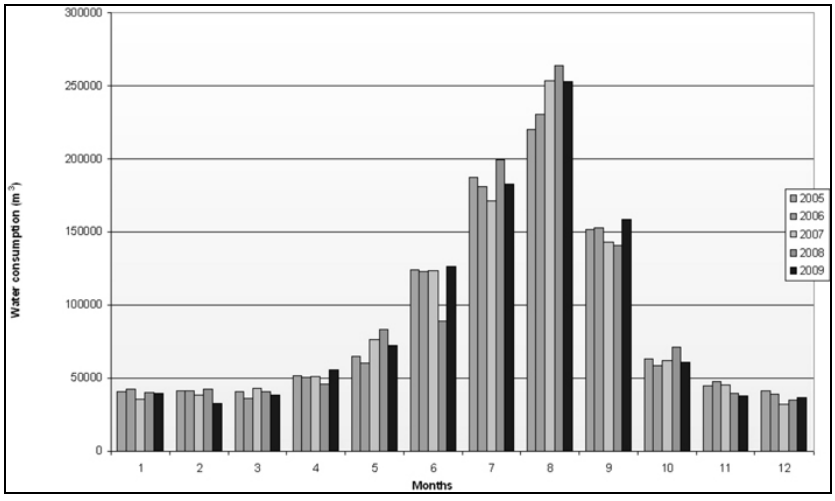

Fig. 3: Discrepancy in the water consumption between summer and winter months – example from the Island of Rab in period 2005-2009 (Rab, 2010).
Sl. 3: Razlika v porabi vode med poletnimi in zimskimi meseci – primer otoka Rab v obdobju med 2005 in 2009 (Rab, 2010).

clined. Emigration processes were more intensive than on the mainland because of a very fragile and inflexible economy which often depended on a single form of the agricultural production (e.g. vineyards).

Demographic trends on the large Kvarner Islands showed relative population stability from the first census in 1857 until the Second World War (Fig. 4). During that period, only the population of Krk Island changed significantly. The population of Krk Island rapidly grew up to 1910 and then started to decrease shortly after the First World War. That process continued up to the 1970's when the number of the inhabitants began to rise again. The rise was caused by the expansion of mass tourism and industry which provided jobs for the islanders and thus stopped emigration and even attracted new inhabitants from the mainland. Such an economic rise was possible because Krk had adequate local water resources which could back up the growing economy (Lončarić, 2010).

The modern demographic processes on other large Kvarner Islands were somewhat different. The islands of Cres and Lošinj started to experience a decrease in population between the world wars because of the changed geopolitical situation. Namely, those islands were annexed by Italy in 1920 after the signing of the Rapalla Agreement which caused many Croats to leave the islands. The opposite process occurred after the Second World War when those islands joined the newly formed Yugoslav state and when many Italian citizens were exiled from the islands. Because of the emigration of both Croats and Italians, the population of Cres and Lošinj islands decreased after the end of the Second World War (Lajić, 2006). Lošinj Island experienced a quicker recovery which was evident from the 1953 census onwards, while Cres Island continued to experience population loss up to 1980, and until the 2001 census its population did not rise but rather remained more or less stable. The population of Rab exhibits a steady growth throughout the shown period. Unlike Cres and Lošinj, Rab had a more constant economic and political development, so the emigration processes were less pronounced.

Demographic trends on the small Kvarner islands were in many ways different than on the large islands. From the first census in 1857 until 1921, the population of the small islands slowly but steadily increased (Fig. 5). But the natural resources of the small Kvarner islands were limited and could not sustain the population growth. Also, vineyards, which were the base of the islands' economy, were heavily affected by a series of diseases (phylloxera, downy mildew, powdery mildew) in the late 19th century (Podgorelec, 1999; Lajić, 2006). The population of the small Kvarner Islands started to decrease shortly after the end of the First World War mainly in response to the emigration of the islanders overseas. The real exodus on the small islands, however, happened after the Second World War. For example, the population of Susak was most affected by emigration since the island lost about 3/4 of its population in the period between the 1948 and 1971 censuses. The population of Ilovik and Unije also rapidly declined, as well as the population of the smallest inhabited Kvarner Islands, Vele and Male Srakane, which were almost completely depopulated by the 2001 census. The remaining population on the small Kvarner islands is very old on average, and therefore possesses no possibility for natural recovery (Podgorelec, 1999). The only way to revive the islands is to stimulate repopulation which is impossible without the development of a modern infrastructure with an emphasis on the water supply systems.

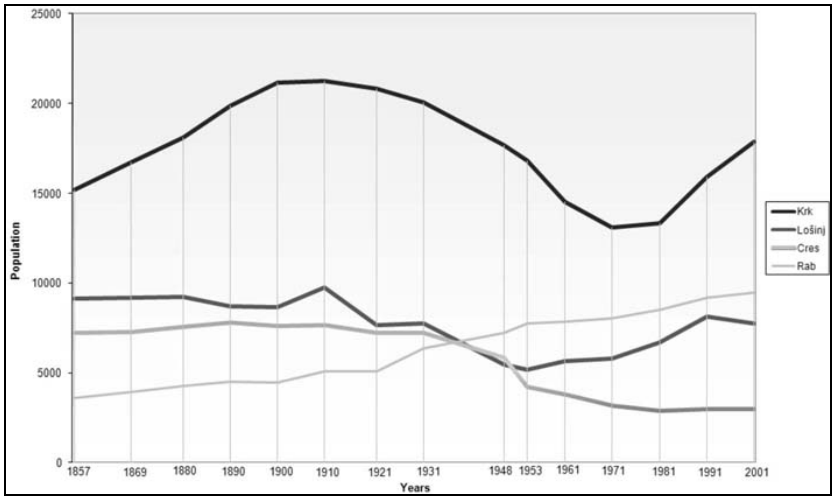

Fig. 4: Population of the large Kvarner Islands from 1857 to 2001 census (Lajić, 2006).
Sl. 4: Prebivalstvo velikih kvarnerskih otokov 1857–2001 (Lajić, 2006).

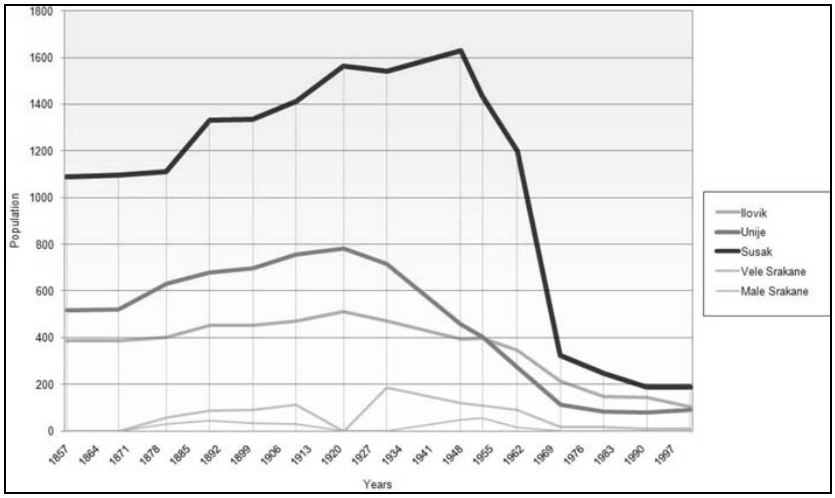

Fig. 5: Population of the small Kvarner islands from 1857 to 2001 census (Lajić, 2006).
Sl. 5: Prebivalstvo malih kvarnerskih otokov 1857–2001 (Lajić, 2006).

Influence of water on the islands' economy

The traditional economy of the Kvarner Islands was based on agriculture, mostly on vineyards and olive growing, as well as livestock farming. Naturally, water sources played a vital role in the development of such an economy. Intensive agriculture was only possible in the areas with substantial amounts of water and with favourable pedological conditions, but on the most of the Kvarner Islands, intensive agriculture existed only in small areas. Rocky karst terrain with almost no soil covers much of the islands and the only form of agriculture that could have existed in such terrain is extensive livestock farming, mostly goats and sheep. The exceptions are the islands of Krk and Rab with relatively large valleys covered with fertile sediments. In combination with the abundance of water sources, those areas provided good conditions for somewhat intensive agriculture production. Flourishing agricultural conditions were able to secure enough food for the local population while surpluses of agricultural products led to the development of trade. The booming economy also positively affected the demographic trends and the islands of Krk and Rab became the most populated among the Kvarner Islands.

In the second half of the 19th century, the once self-sufficient economy of the Kvarner Islands was slowly turning into a market economy. The islanders could export their products abroad and make more money; it also meant that they became dependant on the prices of their goods on the international market. In the event of an economic crisis, such economy could not have transformed quick enough to secure regular incomes, leaving the islanders with no option but to leave the islands and migrate to the mainland or, more frequently, overseas (Lajić, 2006).

Very limited natural resources represented a major setback for the economy of the islands. Water shortages were in fact, one of the leading push-factors of emigration over the last century (Magaš, 1999). The islands' growing population in the early 1900's faced the issues of a lack of both arable land and fresh water. The large islands had more abundant natural resources, most importantly water, which provided a more stable base for economic development. The economy on the large islands was not so heavily dependant on agriculture. Tourism appeared on the Kvarner Islands in the late 19th century, and along with transportation and industry, it created a new economic base for the large islands, making them more resistant to crisis.

The modern economy of the Kvarner Islands depends almost exclusively on tourism. Economic transformation of the Kvarner Islands started a lot earlier than on the rest of the Croatian islands. In the late 19th century, the island of Lošinj was already well known among travellers in the Austro-Hungarian Empire and few hotels and restaurants were built in the town of Mali Lošinj (presently the largest settlement on all the Croatian islands with a population of 6,296). It was not long before the rest of the Kvarner islands were also discovered by tourists and by the beginning of the 20th century Kvarner became the tourist centre of Croatia. Presently, the Kvarner Islands are very popular among foreign tourists, especially Germans, Slovenians and Italians (Kerma et al., 2009).

Intensive tourism, similar to agriculture, could develop only on the islands with sufficient water resources, thus the issue of water availability began to play an even larger role with the development of mass tourism in the 1960's and 1970's. During that period, numerous hotels, camps and tourist settlements were built on the large

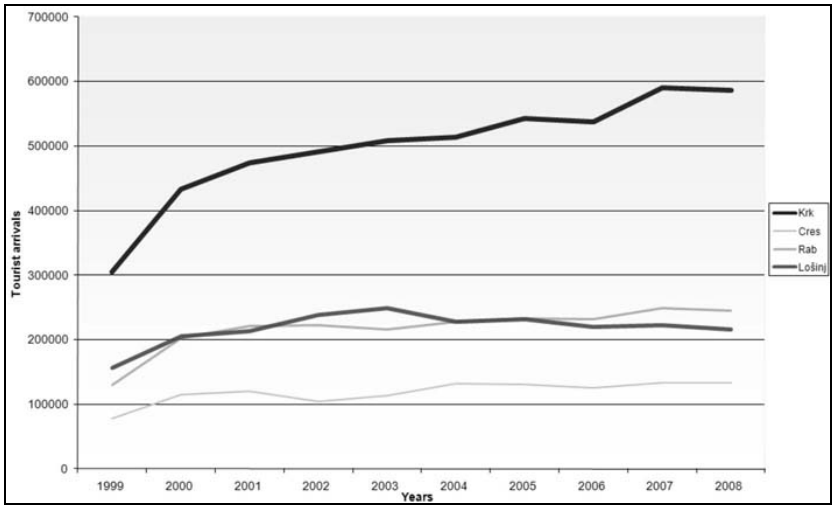

Fig. 6: Numbers of tourist arrivals on the large Kvarner islands from 1999 to 2008 (CBS, 2000–2009).
Sl. 6: Število prihodov turistov na velike kvarnerske otoke 1999-2008 (CBS, 2000–2009).

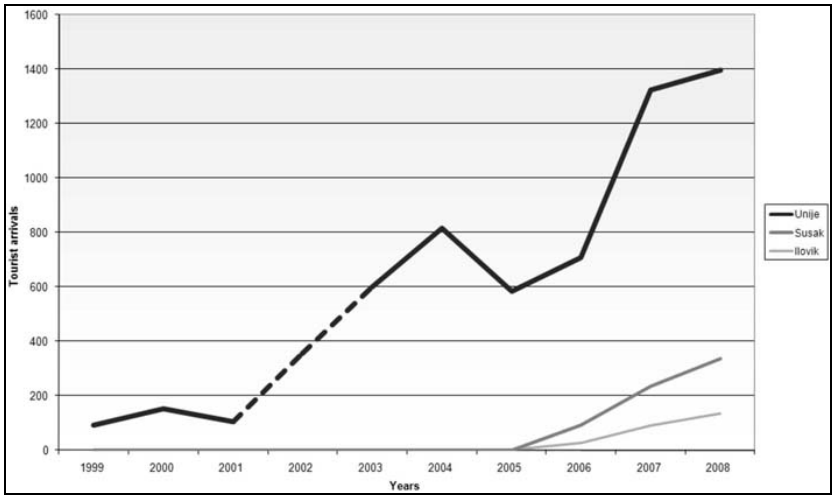

Fig. 7: Numbers of tourist arrivals on the small Kvarner islands from 1999 to 2008 (CBS, 2000–2009).
Sl. 7: Število prihodov turistov na male kvarnerske otoke 1999-2008 (CBS, 2000–2009).

Kvarner islands, resulting in a significant increase in the number of tourist arrivals. Such an increase continued until the early 1990's until the outbreak of the Homeland War in Croatia, which brought tourism on the Kvarner Islands almost to a standstill. After the end of the war in 1995, the numbers began to increase at a slow but steady rate, especially after 1999 when the whole region was politically stabilized (Fig. 6).

Tourism on the small Kvarner islands is still in the initial phase. The islands' tourist infrastructure is very much lacking because there are no hotels, camps or apartment complexes. These islands also have a very small and on average a very old population which limits economic growth due to the labour shortage. Natural water sources on the islands are very limited, so they often depend on the transportation of water from the large neighbouring islands (i.e. the Island of Lošinj). In such conditions, the small Kvarner islands can only receive a very small and limited number of tourists, although the figures are showing growth in recent years (Fig. 7).

Presently, water supply capabilities of the large Kvarner islands are able to provide sufficient amounts for the local economies while the future demands for the water will depend entirely on the rate of tourism growth. Nevertheless, according to the local water distributors, the water sources of the large Kvarner islands can easily keep up with a current steady growth of tourism (ca 2–5% a year), thus there is no immediate danger of a water shortage on those islands.

The alternative sources of fresh water on the Kvarner Islands

Although water resources of the Kvarner Islands are rather abundant, they are exposed to numerous threats, both natural and man-made. Since some large Kvarner Islands depend on a single water source, and small ones were not connected to the waterworks of the neighbouring large islands or the mainland (mostly due to the high expense), non-conventional (alternative) methods should be introduced, in order to provide sufficient quantity of water in the case of increased demands or any unexpected event. Alternative water supply systems range from relatively simple usage of rainwater to the complex and expensive processes of desalination and waste-water treatment.

One potential non-conventional method for obtaining fresh water is recycling waste water. This method is used extensively in arid and semi-arid areas in the developed countries (e.g. Gulf countries, and the south-western states in the USA). Through a series of mechanical and chemical processes, waste water can be purified to the level where it is suitable for irrigation and for use in industry (Tedeschi, 1998). In extreme cases, even drinking water can be obtained through the process of waste water recycling, but such a process is very expensive and it is only used in regions with no alternative water sources. Waste water recycling could be used on the small Kvarner islands, but the costs by far exceed the benefits due to the fact that the construction cost of efficient treatment system is very high, especially for small and medium size communities (e.g. in Cyprus, Turkey, Jordan and Morocco, Fatta et al. 2005; Haruvy, 1997). Moreover, the small Kvarner islands have no public sewage system which could collect waste water. That water is regularly disposed of in private septic tanks. Such tanks, if built improperly, become a threat for the islands' aquifers.

Desalination of the brackish water or sea water has been often considered one of the possible methods for the production of fresh water on the Kvarner islands. But, as in the case of waste water recycling, desalination is still a very expensive process (Buljan et al., 2006) which is not likely to be used in the near future. The only Croatian island with a functional facility for desalination is Lastovo Island in southern Croatia. The cost of production is relatively small (0.65 € per m^3 of water), but the cost of construction of such facility significantly raises the commercial price of water (Sekulić, 1998; Bujan et al., 2006). Desalination should not be the primary water source on the islands, but it can be used as a back-up system in case of emergency (Falkland, 1991).

Another non-conventional method of water supply includes extensive usage of rainwater which has been traditionally used as a source of fresh water on islands worldwide. However, upon development of modern waterworks, being far more reliable source of water than the local reservoirs, rainwater lost its importance (Falkland, 1991; Margeta, 1998). With an average annual precipitation from 950 to 1,500 mm, the Kvarner Islands have excellent preconditions for the usage of rainwater in households. Furthermore, many households on the islands, especially the older houses, already have their own reservoirs for rainwater storage. Besides, there was often at least one large public reservoir in the centre of each settlement from which the water was distributed to households. Hence, there is no need for large investments in infrastructure. Rainwater is considered to be of high quality, especially if collected from clean surfaces; any mechanical pollution that may occur during the collection of the rainwater can easily be removed by simple and cheap filters. Such water is ready for use in households even as a drinking water.

Accordingly, the use of rainwater is the only non-conventional method of water supplying that has development potential on the small Kvarner islands. In fact, even large islands should not neglect the development of non-conventional water supplying methods because present water resources are not unlimited. Also, the risk of pollution of the aquifers is constantly present, particularly in the peak of the tourist season. In the case of pollution, islands would be left with no alternative sources of fresh water. Such an event is very possible on the islands of Cres and Lošinj where the Vransko Jezero Lake is the only source of fresh water. The islands of Krk and Rab are not so threatened because of their connection to the mainland's waterworks. Rainwater collected during the wet season could be used during the summer season primarily in agriculture and industry thus relieving the pressure on the conventional water sources which, in turn, can be used only for public purposes.

Potential threats to the water sources on the Kvarner Islands

Generally, karst aquifers are very complicated and sensitive hydrogeological systems which quickly react to changes within its surroundings. Due to the groundwater circulation through the complex systems of fissures, catchment areas of some karst aquifers can be very large, thus making them exposed to various threats (Ford, Williams, 2007). Those threats are mostly of human origin, but certain natural processes can also have a negative impact on the quantity and quality of water in karst aquifers (Bonacci, 1987).

The biggest natural risk for the islands' aquifers comes from a potential rise in sea-level which would cause flooding of the coastal zones, intensified erosion of the coasts, and most importantly, the intrusion of sea water in the coastal aquifers (Barić et al., 2008). Although a slow long-term regional tectonic uplift was recorded in the Krk Island region (Surić et al., 2009), the sum of recent global and local processes have resulted

in a relative rise in sea-level within the Kvarner region. Also, there are several short-termed processes with a significant impact on sea level. Those processes are capable of inflicting massive damage to coastal regions, including aquifers, in a very short period of time. The most pronounced short-term processes include storm surges and extreme waves (Pasarić, Orlić, 2001).

Although natural risks cannot be neglected, human impact is by far more dangerous for the islands' aquifers. The major threats are urban, touristic, and industrial zones, as well as intensive agriculture and traffic. Also, a considerable amount of pollution comes directly from households. Islands, especially the small ones, often have very ineffective sewage systems, and the groundwater is usually contaminated by wastewaters from the poorly constructed septic tanks. Furthermore, inadequate disposal of household garbage in sinkholes pits or abandoned quarries can easily pollute surface and groundwater (Falkland, 1991). Due to a relatively high concentration of population and various economic activities, the Kvarner islands are considered a high-risk zone of water pollution, especially the coastal zones due to tourism.

Potential risks do not include only chemical, biological or mechanical pollution, but also an excessive pumping of water which can cause a serious decline in the quality of water or, in extreme cases, the destruction of the aquifer. Protection of the water sources should be top priority for local communities on the Kvarner Islands. Any disturbance in the water supply, especially during the tourist season, would cause a serious money loss and a general slowing down of the islands' economic development.

All water resources on Kvarner Islands, including their catchments as well as the groundwater retentions, are protected in forms of water supply reserves. Monitoring of the groundwater quality is conducted 6 to 12 times every year, and measurements show that most of the time groundwater is of exceptional quality. A decrease in water quality appears only after long periods of drought followed by heavy rains. In the case of sudden pollution, the local government applies a *State Plan for Water Protection* which provides a series of measures for quick response to pollution.

Further protection of the water resources is secured through the state legislative on protected areas. In the Republic of Croatia, there are 9 categories of protected areas. Their main aim, regardless of the level of protection which they grant, is to preserve the nature in its initial state. The highest level of legal protection is provided for Vransko Jezero Lake, Vransko Lake near the town of Njivice, and Ponikve Lake which are all special reserves. Some water resources are protected as natural monuments (e.g. Pidoka Spring and Mlinica Spring on the Island of Rab), while some are located within areas protected as a significant landscapes (e.g. Vela Rika Stream in the Bašćanska Draga Valley). In all the aforementioned protected areas, any human activity which could endanger the present state of nature is strictly forbidden.

CONCLUSION

A lack of water has often proved to be the factor of limitation of economic development on the Croatian islands. However, in contrast to the most of the Croatian archipelago, the Kvarner Islands contain significant water sources which simplifies water supply of the islands thus creating favourable conditions for economic growth based on mass tourism. On the other hand, the seasonality of tourism has put huge pressure on the water supply infrastructure because water consumption on the islands is several times higher during the summer months than in the winter. But, given the current trends in demographic and economic progress on the Kvarner islands, the present water supply systems can secure more than enough water for the local communities in the near future. The situation on the small inhabited Kvarner islands is completely the opposite. Since those islands are not connected to the waterworks of the neighbouring large islands, water is provided from the scarce local water sources as well as from supply ships. Such conditions undermine any serious economic activity, especially the development of tourism, which in turn has a negative impact on the demographic trends since those islands suffer from heavy depopulation. Any future attempts for the islands' economic and demographic revival should start from solving problem of the water supply.

Mostly due to their relatively small size, the Kvarner Islands are very fragile ecosystems, with the water sources being especially vulnerable. Karstic terrain, which prevails on the Kvarner Islands, is highly permeable so any pollution that occurs on the surface can very quickly infiltrate and reach the groundwater. The risk of water pollution is growing with the development of tourism and, in some cases (i.e. the Island of Krk), industry. Most of the Kvarner Islands depend on one or two water sources, which means that pollution of even a single water source could seriously endanger or even halt the water supply on an island. In the case of such events, the islands' communities should be able to use alternative water sources, such as rainwater or processed waste water to compensate the losses. But, the alternative water sources are rarely used, despite being sometimes cheaper and easier to use (i.e. collecting rainwater) in comparison to the conventional water sources.

Availability of water has been a key factor of the demographic and economic development of the Kvarner Islands throughout history. In the conditions of a modern tourism-based economy, only those islands with significant water resources can expect future progress, providing that the principles of sustainable development are applied.

VPLIV RAZPOLOŽLJIVOSTI VODE NA ZGODOVINSKI, DEMOGRAFSKI IN EKONOMSKI RAZVOJ KVARNERSKIH OTOKOV (HRVAŠKA)

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POVZETEK

Razpoložljivost vodnih virov je vedno predstavljala temelj gospodarskega in socialnega napredka kvarnerskih otokov. Konec 19. in v začetku 20. stoletja je bilo tradicionalno gospodarstvo podvrženo procesu preoblikovanja. Vloga vodilne gospodarske moči je s kmetijstva počasi prehajala na turizem, ladjedelništvo in trgovsko prevozništvo. S preseljevanjem prebivalstva iz vasi in notranjosti otokov proti obali pa je novo gospodarstvo sprožilo tudi demografske spremembe.

Po drugi svetovni vojni je vlogo gonilne sile otoškega gospodarstva prevzel masovni turizem. Gospodarski napredek je bil mogoč le na velikih otokih, saj manjši otoki zaradi omejenih naravnih virov, zlasti vode, niso mogli izpolniti zahtev rastočega gospodarstva. V drugi polovici 20. stoletja se je prebivalstvo manjših otokov Kvarnerja začelo množično izseljevati, tako na celino kot tudi v tujino.

Množični turizem je spodbudil naložbe v infrastrukturo otokov. V šestdesetih in sedemdesetih letih prejšnjega stoletja je bila na velikih otokih zgrajena vodovodna mreža, medtem ko so manjši otoki morali še naprej shajati s svojimi lokalnimi vodnimi viri in so pogosto trpeli pomanjkanje vode. Sedanji sistem oskrbe z vodo na kvarnerskih otokih lokalnemu prebivalstvu in gospodarstvu zagotavlja zadostne količine vode. Prav tako se na otokih zaradi izredno počasne rasti prebivalstva in gospodarstva v bližnji prihodnosti ne pričakuje znatnega povečanja potreb po pitni vodi. Manjši kvarnerski otoki lahko demografsko in gospodarsko oživitev pričakujejo šele, ko in če bo problem oskrbe s pitno vodo ustrezno rešen.

Otoki Kvarnerja predstavljajo območje visokega tveganja za onesnaženje vode. Čeprav glavno grožnjo predstavlja turizem, pa ne smemo zanemariti vpliva gospodinjstva. Otoški vodonosniki so zelo krhki in vsakršno dolgoročno onesnaževanje bi za gospodarstvo pomenilo velik korak nazaj. Prednostna naloga lokalnih skupnosti je zato zmanjšanje možnih tveganj in zagotavljanje rezervnih vodnih virov za nujne primere.

Ključne besede: otoki, voda, gospodarstvo, turizem, Kvarner, Hrvaška

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