Does the River Continuum Concept work in small rivers that begin from swamps?

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This study was made to find out if the original idea of river continuum concept works also in northern coniferous forest areas in a small river, and if the idea can be used in environmental ecology courses in upper secondary schools. The research was carried out in three different points in Tampinjoki – Hanhijoki – Emolanjoki. Samples of biological and hydrological – morphological factors were taken from every part of the river, analyzed and then compared to the original theory. The study was made with simple equipment that can usually be found in schools, and at the time when environmental ecology courses usually take place in schools. The results followed the river continuum concept quite well with a little exception of invertebrates in the second research point. By connecting the results with analyses made by the city of Mikkeli, current information of the condition of the river was gotten. Invertebrates, vegetation and the analyses showed some signs of eutrophication especially in the last part of the river. These results can also be used when planning new constructions to the area or monitoring the development of the state of the river if the research is continued annually by students. Protecting and developing the river with the help of these results can help to maintain biodiversity and beauty of the environment, and allow the versatile use of the area.

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Acknowledgements

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Biography

Noora Nuutinen is a 17-year-old girl who studies at Mikkelin Yhteiskoulun lukio, an upper secondary school in Finland. Her hobbies are riding and photographing. Tiina Pippuri is an 18-year-old-girl from Finland, who also studies at Mikkelin Yhteiskoulun lukio. She is interested in music and riding. They both took part in the Combat Climate Change competition of National Geographic, and in 2007 they participated in Youth Bios Olympiad in St. Petersburg.

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1. Introduction

In 1980 Robert Vannote developed a theory of The River Continuum Concept (RCC). According to the theory, the functions of a river can not be understood by examining only a small part of it, because the river changes constantly towards the lower reach. This theory disproved the previous way to study a river like a lake.

The RiverLife-project, put into practice in Finland in 1998-2001 with the support of the European Union, endeavored to maintain and improve the water quality of rivers. With the help of the project, it was possible to advance ecologically sustainable land use, and create a basis for monitoring the rivers in an economically profitable way.

The purpose of this study is to find out if the original river continuum concept idea is valid enough also in northern coniferous forest areas, especially in rivers beginning from swamp and in small drainage areas, and if the idea works despite the season. Another purpose of this study is to develop a method suitable for river studies in environmental ecology courses of upper secondary schools (National Core Curriculum for Upper Secondary Schools 2003) . The samples were taken in late autumn, 4th of November. The exploratory area of this study is situated in South-Savo, in the eastern part of Finland. The river begins from a drained swamp and streams through the city, ending in the harbor area. The beginning of the river belongs to Natura 2000 –area. The mission of the project is to protect the survival of certain species and environments in Europe.

2. Theoretical background

According to Vannote (1980) RCC studies the river as a whole longitudinal ecosystem. The stream forms a balance between width, depth, velocity, biological factors, sediment load and temperature. The pattern of the river can be predicted, because a small change in one of these factors affects the whole system. In every phase of the river material is produced, released and stored. Because of the availability of food, invertebrates show longitudinal variety. They are divided in functional groups: shredders, collectors, grazers and predators. Predators are found in every phase of the river. Later the theory has been tested and developed further in several studies. (Leopold, Wolman & Miller. 1964)

RCC divides the river in three sections: headwaters, mid reach and lower reach. The stream is shadowed by riparian vegetation at the headwaters, and that causes the stream to be

heterotrophic, because photosynthesis decreases. The ratio between producing and consumption is less than 1. The fauna consists of shredders and collectors.

The stream changes from heterotrophic to autotrophic during the mid reach when the shading influence of vegetation decreases. Producing is greater than consumption in this part of the river. The river continuum theory divides headwaters and mid reaches in altogether six parts. In deciduous and coniferous forests, this change takes place at about stream order three. In mid reaches the fauna consists of grazers and collectors.

In the lower reaches the stream is full of whirls, and vegetation is not able to attach to the bottom of the river. That's why the river is no longer autotrophic. Some phytoplankton and macrophytes can be found, but they are not enough to make the river autotrophic. The consumption is again greater than producing. Also in the lower reaches the collectors are the biggest group of organisms.

RCC was developed based on data from continental streams. Groff (2006) has earlier found out that the patterns in the longitudinal variation matched RCC predictions but for example total species richness, insect species richness and the percent composition of collecting organisms did not in tropical small rivers. In Finnish Ostrobothnia the RiverLife-project (Karjalainen S. M. & Heikkinen, K. 2005) had three target rivers. The goal of the project was to produce information about the river ecosystems and suitable protection methods. Moreover, problem solving models for rivers were looked for. Some problems that emerged were for example eutrophication and the increase of sludge on the bottom. Also in the RiverLife-project the river was studied in pieces from headwaters to lower reaches. According to the project, every part of the river influences its own ecosystem.

The European Union has founded Natura 2000 –network (European Commission 1999), to ensure that the nature conservation is in a high enough level and that the decrease of natural diversity will be stopped. In Finland, the Natura 2000 –project has an area of about 4, 8 million hectares.

The beginning of the river in this study belongs to Hanhilampi's Natura 2000-area, which is about 29 hectares. Primarily important targets for protection in this area are borealic coniferous forests and the flying squirrel (Pteromys volans) The protection is carried out on grounds of nature conservation law. (Suomen ympäristökeskus SYKE, 2006)

3. Hypothesis

The hypothesis is that river continuum theory modeling can be utilized in a Finnish small river ecosystem that begins from a swamp, which is typical for Finnish rivers. How is the

river continuum theory suitable for a research target of environmental ecology in upper secondary schools? How can the results be utilized in planning the land use and nature protection of the area? And how can the students take part in this?

4. Research area

The research point is located in Mikkeli, 61° 5” N 27° E. The researched river Tampinjoki – Hanhijoki – Emolanjoki is 9,7 kilometres long and has two tributaries. It begins from a ditched swamp south of Mikkeli, and it continues in a riverbed bordered with rocks towards the outdoor recreation area of Kalevankangas. Typical for the terrain are even sandy areas where spruces grow, kettle holes and eskers. The research was done in three different points. (ATTACHMENT 1) The first point, situated in the Kalevankangas forest area represents the headwaters of the river. The area is in its natural state and belongs to the Natura 2000 –project.

Before the second point, another river, Siekkilänjoki – Pankajoki unites with Tampinjoki from the south through Hanhilampi. The river changes its name to Hanhijoki. Sirkkapuro unites with the river from the north, and the name changes again to Emolanjoki. It flows in a riverbed in a terrain which is mainly covered with deciduous trees. The end of the riverbed is modified. Some decades ago a dam was operating in Emolanjoki. Its hydroelectric power was used by a mill. Lastly the river flows through settlement and industrial areas and flows into Mikkeli’s dock which is a part of Finland’s biggest lake Saimaa. The beginning point of the river is 112 meters above the sea level, whereas the ending point flowing into Saimaa is 36 meters lower than the beginning point. The altitude difference is therefore quite big.

5. Carrying out the research

This research was conducted in three different points of the Tampinjoki – Hanhijoki- Emolanjoki area. The factors examined are divided into three groups, which are biological, hydrological – morphological and chemical – physical.

(FIG 1) *10 meters were measured from the river.*

(FIG 2) *The velocity was counted after measuring.*

Hydrological – morfological factors are velocity of the water, different obstacles like dams and waterfalls, structure of the bank, sediment load, variety in depth and width and possible groundwater formations. The depth was measured in the middle of the river. The velocity was studied by measuring 10 meters from the river and counting the time it took a 5-centimeter-long wooden stick to move that distance in the middle of the river. (Fig 1, Fig 2) River barriers and groundwater formations were checked from a map. Sediment load was examined by placing a plankton net horizontally against the river bottom for one minute. The matter was poured on a glassy dish.

Biological factors are water vegetation, ground fauna and fish. Fish could not be quantified with school equipment.

(FIG 3) *Invertebrates were caught with a net.*

(FIG 4) *Ground fauna was collected with tweezers*

The ground fauna was examined with a net whose diameter was 25 centimeters. The mesh size was 2 millimeters. The net was moved along the river bottom with sawing movements towards the higher reaches. (Fig 3) The matter attached to the net was poured into a flat dish and the invertebrates were collected with tweezers to a dish containing ethanol. (Fig 4) The classification of water vegetation was done in depth according to a profile drawn from a line.

(FIG 5) *The solid matter was extracted to cyklohexane in a funnel.*

According to Jouko Ahola (Personal announcement, 2008) the weigh of sediment can be studied in the following way. The extra water was filtered away from the sediment load, so the matter got stuck to the filter papers. The papers were left to dry, after which the solid matter was extracted to cyklohexane in a funnel. (Fig 5, Fig 6) The filtrate was dropped into an evaporation bowl which had been weighed beforehand, and cyklohexane was carefully evaporated in a fume cupboard. After the evaporation bowls had cooled down, they were weighed. (Fig 8, Fig 9) By comparing the mass of the empty evaporation bowl to this final result, the inorganic matter in the sample was discovered.

The ground fauna was examined with a binocular and their species were delineated as accurately as possible with the help of literature.

(FIG 7) *The extra water was filtered away.*

(FIG 8) *Evaporation bowls were cooled down in exicator.*

(FIG 9) *Cooled evaporation bowls were weighed.*

6. Results and discussion

The first research point (Fig. 10) by the river Tampinjoki is almost in its natural state. There are a lot of sand eskers from the last Ice Age. A jogging track goes by the region and a lean-to for hikers is located nearby. Settlement areas or roads are not situated near the river. The bed of the river is at the depth of about one meter and it's about 2,6 meters wide. The depth is 26 centimeters on average. The velocity of Tampinjoki is 0,25 meters per second. The entire water amount flowing through the river is 0, 16 m^3/s. Riverside vegetation is abundant and because of their close location to the river, fallen trees make the flow more difficult. The river is bordered with the following plants: birch (Betula pendula), spruce (Picea abies), grey alder (Alnus incana), red-stemmed feather moss (Pleurozium schreberi) and lady fern (Athyrium filix-femina). Vegetation was not found in the river bed. (Table 1)

(FIG 10) *Tampinjoki 4.11.2007.*

TAMPINJOKI	
birch	*(Betula pendula)*
spruce	*(Picea abies)*
grey alder	*(Alnus incana)*
lady fern	*(Athyrium filix-femina)*
red-stemmed feather moss	*(Pleurozium schreberi)*

(TABLE 1) *Vegetation in Tampinjoki-area.*

The second research point (Fig 11) by the river Hanhijoki is located in the vicinity of paved roads and settlement areas. The current is strong and the bottom quite rocky. The riverbed is about 5,80 meters wide and 79 centimeters deep. At this point the velocity is 0,56 meters per

second. The entire water amount is 2,566m^3/s. The trees are a little bit far away from the riverbed. That may be caused by regular floods. The vegetation of the area consists of lady fern (Athyrium filix-femina), narrow buckler fern (Dryopteris carthusiana), grey alder (Alnus Incana), spruce (Picea Abies), birch (Betula pendula) and different willows (Salix sp.). (Table 2)

HANHIJOKI	
birch	*(Betula pendula)*
spruce	*(Picea abies)*
grey alder	*(Alnus incana)*
lady fern	*(Athyrium filix-femina)*
narrow buckler fern	*(Dryopteris carthusiana)*
willow	*(Salix sp.)*

(FIG 11) *Hanhijoki 4.11.2007.*

(TABLE 2) *Vegetation of Hanhijoki-area.*

Between the second and the third research point the river streams through the district of Emola. There are settlement areas, busy paved roads and industrial areas near the river. In the third research point (Fig. 12) the riverbed is clearly modified. The width is 11,38 meters and depth 110 centimeters. Velocity was 0,17 meters per second at this part of the river. The entire water amount is 2,128m^3/s. The plants that were found were willow (Salix sp.) white willow (Salix sipirica), sedge, (Carex sp.), purple small-reed (Calamagrostis canesces), birch (Betula pendula) yellow water lily (Nuphar lutea), iris (Iris pseudacorus), swamp meadow-grass (Poa palustris) and common reed (Pharghmites australis). (Table 3)

EMOLANJOKI	
birch	*(Betula pendula)*
willow	*(Salix sp.)*
white willow	*(Salix sipirica)*
swamp meadow-grass	*(Poa palustris)*
common reed	*(Pharghmites australis)*
iris	*(Iris pseudacorus)*
purple small-reed	*(Calamagrostis canescens)*
sedge	*(Carex sp.)*
yellow water lily	*(Nuphar lutea)*

(FIG 12) *Emolanjoki 4.11.2007.*

(TABLE 3) *Vegetation of Emolanjoki-area.*

According to a definition made in autumn of 2006 by Environmental Services of the City of Mikkeli (information system Hertta, 2008) the water of the tributary Siekkilänjoki – Pankajoki flowing into Hanhilampi is quite eutrophicated. The entire nitrogen content is 1800 µg/l.

In areas and rivers where agriculture is common, the number is usually over 2000 µg/l, but in waters that are clear and in their natural states it is only about 200µg/l. These numbers include all the forms of nitrogen, like nitrite and nitrate. The amount of nitrogen changes along the seasons. It is in its highest during the winter because photosynthesis is slight due to the small amount of light and cold temperature. Vegetation consumes nitrogen in the summer. In Sirkkapuro, the other tributary, the nitrogen content is 550µg/l according to an analysis made in 2007.

The entire phosphorus content in Pankajoki was 24 µg/l. The plants need phosphorus, and with the help of it, eutrophication can be measured. The biggest amounts of phosphorus are washed away to water systems from fields and agriculture. According to Water Government classification (1988) 12-30 µg/l is a signal of slightly eutrophicated water system. In Sirkkapuro, the corresponding number was 14 µg/l. It's on the edge being slightly eutrophicated. Sirkkapuro begins from Särkijärvi and there are summer apartments by the river.

The analysis done in Hanhijoki in 2000 (information system Hertta, 2008)) showed that the quality of water was quite good. The entire nitrogen content was 470µg/l and phosphorus content 15 µg/l. Samples taken from Rokkalanjoki in 2004 showed that these contents had slightly risen because then the content of nitrogen was 850 µg/l and phosphorus 18 µg/l. All these analyses were made in autumn.

The contents of soluble oxygen were very good in every river at the time of the analyses. In Hanhijoki it was 8,1 mg/l and in Rokkalanjoki 11,8 mg/l. The content is excellent between 7-20 mg/l and satisfying between 4-6 mg/l.

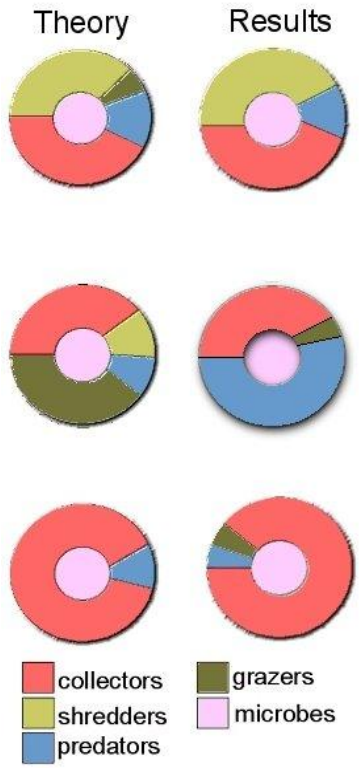
The inorganic sediment load of the first research point weighed 0, 10 grams. In the first phases of the river there is only little water so the heavy matter of the bottom does not move forward with the stream. Because of the natural state of the river erosion does not free matter from the bottom. The Finnish autumn is a very rainy season so there can be even more water than normally. The bottom of the river was soft, and several trees had fallen to the riverbed.

There was hardly any inorganic sediment load in the second point, but the flow of the water is stronger, so in its entirety more matter is released. There is no erosion in this part of the river so it is in its natural state. The great majority of the sample was organic matter. The trees are far from the riverbed so the leaves do not fall to the river. The river bottom consisted of sand and rocks of all sizes.

A great amount of water flows through the third research point, but because of slow velocity the inorganic sediment load was very small, 0, 02 grams. However, the riverbed is clearly modified for example with dams so they can affect the amount of sediment. The riverbanks are very steep and bordered with rocks.

The patterns in the longitudinal variation matched RCC predictions . The total number of species and the species richness in each point was small because the way of collecting the sample was very rough (the mesh size 2 mm). In the first point mayfly (Ephemera vulgata) and two chironomid larvae (Chironomidae) belong to collectors, and caddisfly larva (Oligostomis reticulata) to shredders. The two stonefly larvae (Plecoptera) are both predators (Fitter & Manuel. 1986).

In the second point, Hanhijoki or the mid reaches, the four mayflies (Ephemera vulgata) and three mosquitoes (Anopheles sp.) and phantom midge (Chaoborus crystallinus) in the sample were collectors, and common bithynia (Bithynia tentaculata) a grazer. Damselfly larva (Calopteryx virgo), diving beetle larva (Dytiscidae) and two different stonefly larvae (Plecoptera) are all predators. (Fitter etc., 1986) (Sandhall & Andersson. 1980.)The most important group of invertebrates was also in this part of river the collectors. Mayflies (Ephemera vulgata) are collectors, and water slater (Asellus aquaticus) a grazer. It lives in polluted waters so it may indicate the condition of the water. The water boatman (Sigara sp.) found in the river is a predator. (Fitter etc., 1986) (TABLE 4)



TAMPINJOKI	
mayfly	*(Ephemera vulgata)*
chironomid larva x2	*(Chironomidae)*
caddisfly larva	*(Oligostomis reticulata)*
stonefly larva	*(Plecoptera)*
stonefly larva	*(Plecoptera)*

HANHIJOKI	
mayfly x4	*(Ephemera vulgata)*
phantom midge	*(Chaoborus crystallinus)*
common bithynia	*(Bithynia tentaculata)*
damselfly larva x7	*(Calopteryx virgo)*
diving beetle larva	*(Dytiscidae)*
stonefly larva	*(Plecoptera)*
stonefly larva x2	*(Plecoptera)*
mosquito x3	*(Anopheles sp.)*

EMOLANJOKI	
mayfly x12	*(Ephemera vulgata)*
water slater	*(Asellus aquaticus)*
water boatman	*(Sigara sp.)*

(TABLE 4) *Invertebrates found in Tampinjoki – Hanhijoki – Emolanjoki compared to original River Continuum Theory*

Tampinjoki – Hanhijoki – Emolanjoki follows RCC surprisingly well, though the drainage area of the river is very small. The number of organisms was also quite scanty. By taking the samples annually, the condition of the river can be monitored regularly. The river continuum theory works as a river ecosystem model where the change of one factor reflects elsewhere. Abiotic factors determine a lot the state of the biotic part. In the first two part of the research the river was in its natural state, and it had not suffered from the actions of the people, but from the results of the third part it can be concluded what the consequences of increased human

actions are. Signals of eutrophication and pollution can be observed in the area between the second and the third point.

The river flows through a settlement area so rain waters wash away possible phosphate and nitrate run offs from the golf course and fields. The fallouts of traffic and other human actions can cause strain to the river. The closest areas of the river should stay outside human actions, and be restricted from construction so they will not have any influence on Saimaa.

Although the phosphorus and nitrogen contents were raised in one tributary of the examined river, Pankajoki, the contents were good in other parts of the river, so possible fallouts in Pankajoki don't seem to affect the other rivers. Phosphorus is one of the greatest causes to eutrophication because it enhances the growth of algae, which affects also the production of other vegetation. Nitrogen has similar effects. The organic matter fallen to the bottom has to be decomposed so the increased decomposer action consumes great amounts of oxygen. In eutrophicated water systems the oxygen loss is a common problem. In the area on Tampinjoki – Hanhijoki – Emolanjoki the oxygen contents were good.

The river ecosystem differs slightly from a lake ecosystem because the water changes constantly and the oxygen loss does not appear in the river. In the case of Tampinjoki – Hanhijoki – Emolanjoki the big amounts of nutrients affect probably the deltas and the lakes the river flows into. The contents of nutrients and oxygen should be carefully followed particularly in the Saimaa area. The area could be protected by planning constructions more far away from the river banks and by reducing the use of phosphorus containing fertilizers as far as possible.

The function of water vegetation as a bio indicator in this particular river is slightly difficult to specify because vegetation attached to the bottom was hardly found in the first two research points. In the headwaters it is not supposed to be found as the food chains begin from leaves fallen to the river. This is also valid in Tampinjoki because the trees near the river bank drop their leaves to the stream.

Although in the second research point vegetation in the river bottom could not be found because of the strong flow, due to big organic sediment load in the middle reaches there probably is a plenty of it. The stream is autotrophic, and the food chains begin from the own production of the river.

Instead, iris (Iris pseudacorus) and sedge (Carex sp.) found in the third point can function as bio indicators. Iris lives in water systems that have plenty of nutrients and almost all sedges in waters that have a lot or quite a lot of nutrients. It can be concluded that between the second and the third research point nutrients flow into the river. (Suomen Luonnonsuojeluliitto 2000) (Messo & Ripatti-Cantell, 1992.)

By examining the ground fauna and their frequencies the condition of the river can be monitored. As the ground fauna is almost stationary and also lives quite long, they are particularly important bio indicators for the long-term changes of their habitat. The appearance of specific special is affected inter alia by vegetation, constitution of sediment, nutrients, salt, oxygen and other species. A part of a river can be monitored as an environment on the grounds of species living in that place. (Hanski, 2007.)

For example, the stonefly larvae (Plecoptera) and common bithynia (Bithynia tentaculata) found in the first and second research point indicate that the river bottom of their environment is almost in its natural state or slightly disrupted. A part of chironomid species (Chironomidae) function as signs of big amounts of nutrients, but the numbers of larvae should be considerably bigger so that eutrophication should be considered. The water slater found in the third research point is a typical invertebrate for polluted waters so it can refer to the eutrophication of the last part of the river. (Fitter etc., 1986) (Messo etc., 1992.) With the help of these methods the whole river ecosystem can be studied accurate enough in environmental ecology courses at schools in small rivers that begin from swamp, which are typical for Finland. Originally one third of Finland's area was swamp. (Häyrinen, 1978)

This research can easily be actualized with simple school equipment that is normally used for example in biology lessons (net, stopwatch, plankton net fabric, string, long waterproof boots, cans, scales, etc.). The biggest problems when carrying out this research were the weighing of sediments loads because all the scales are not accurate enough, and the precise definition of species. The number of ground fauna was also too small. Upper secondary schools that are located near the river could carry out this kind of research annually so at the same time the condition of the river would be monitored. This monitoring can be used as a tool of environmental education by protecting a river that is typical for one's own home town.

The condition of the river should therefore be monitored with the help of ground fauna instead of just abiotic factors. Invertebrates reflect the change immediately by disappearing or appearing in the river. If just nitrogen and phosphorus contents are examined, they don't indicate the real state of the river. When the ground fauna is studied annually by the students, the amount of nutrients that really influences the river can be observed.

By studying regularly the ground fauna and their distribution to above-mentioned groups, clues from the changes in abiotic factors of the river can be detected. If changes do not occur in the watershed, the sediment load is not likely to change. The results gotten in this study can be used as a basis if construction will happen in this area.

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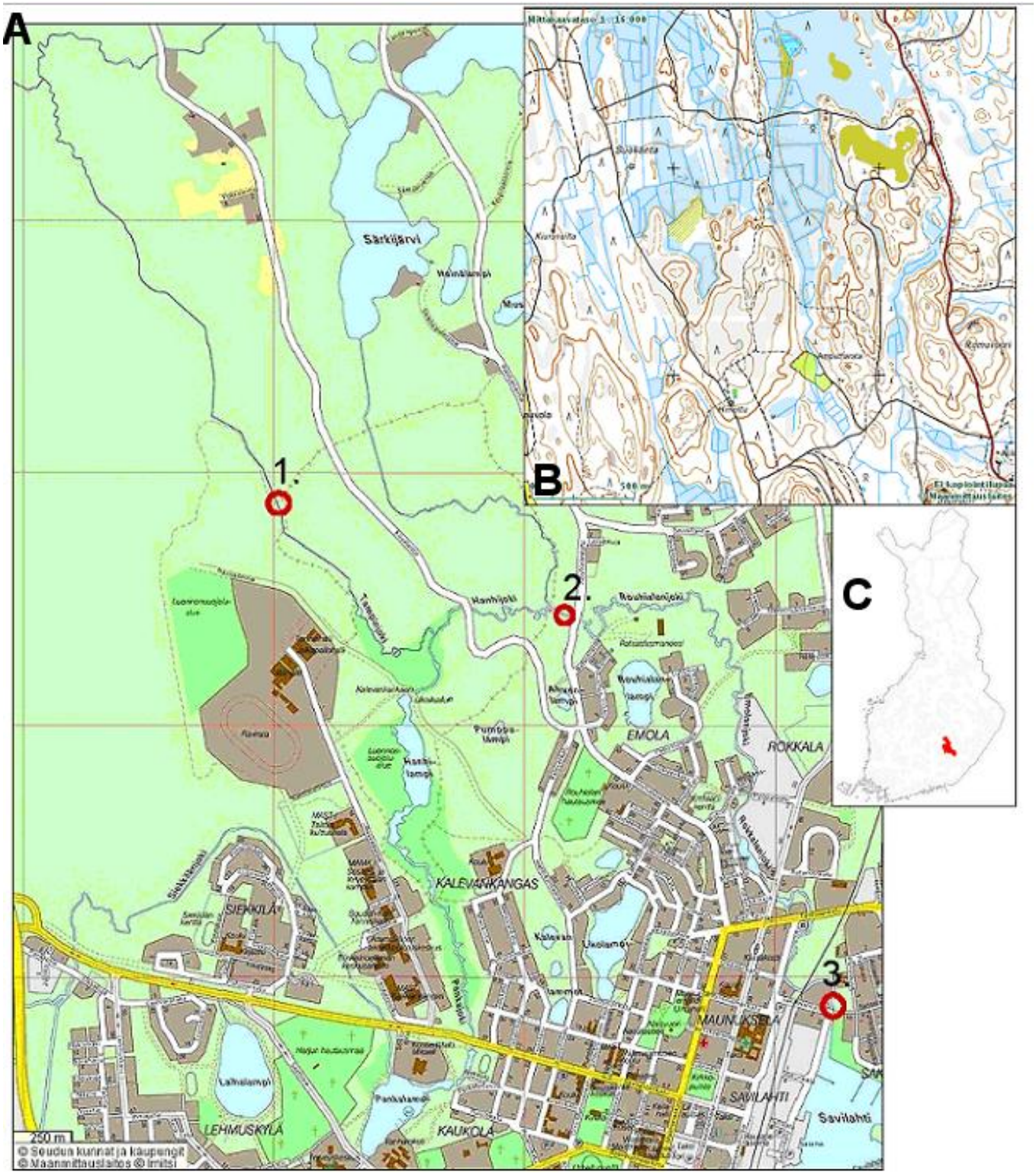

(ATTACHMENT 1)

A: *The research points in a map (Source: http://map3.centroid.fi/mikkelinseutu/map.php)*

B: *The beginning of Tampinjoki – Hanhijoki – Emolanjoki (Source: www. kansalaisen.karttapaikka.fi)*

C: *Finland and the city of Mikkeli*