Preliminary research report

Dendrochronologia 19 (2) - 2001: 221 - 229

A regional larch chronology of trees and historical buildings from Slovenia and Northern Italy

Tom Levanič*, Olivia Pignatelli**, Katarina Čufar***

** Slovenian Forestry Institute, Večna pot 2, SI-1000 Ljubljana - Slovenia*

*** Dendrodata, Via Cesiolo, 18, I- 37126 Verona - Italy*

**** Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Rožna dolina - Cesta VIII/34, SI-1000 Ljubljana - Slovenia*

Abstract

Chronologies of living trees of larch (*Larix decidua* Mill.) from the alpine forest sites in Slovenia and NE Italy, as well as mean curves of historic buildings from Piran (Slo), Venice (It), and Aquileia (It) were constructed and used to build a 1242 year long regional chronology spanning the period AD 756-1997. It is currently the only chronology based on samples of wood from Slovenia and NE Italy and among the longest chronologies in the region south of the Alps. Its comparison with millenary larch chronologies from Tyrol and Dachstein (Austria) and from the NE Italian Alps showed a good teleconnection of tree-ring patterns.

Keywords: *Larix decidua* Mill., dendrochronology, tree-ring widths, Alps, Adria

Introduction

Long regional chronologies are needed both for dating and the study of long-term environmental fluctuations and trends. Such chronologies are rare in the Alpine region due to the scarcity of long-lived trees and low availability of samples other than from standing trees. Larch (*Larix decidua* Mill.) is among the most appropriate alpine tree species with which to construct long chronologies. It has often been reported that individual trees can survive over 500 and up to 1000 years (e.g. Schweingruber 1992, Gassmann et al. 2000). Due to its high durability the larch wood in constructions and in stems of dead trees can remain well preserved over the centuries (e.g. Levanič et al. 1997, Grabner et al. 2001).

Larch has often been used in dendrochronological studies. In the last decade most tree-ring studies in larch from the Alpine region have been focused on its stand dynamics (Nola 1994; Motta, Masarin 1996; Urbinati, Carrer 1996; Carrer 1997; Motta et al. 1999), ecology (Belingard, Tessier 1993; Nola 1994; Petitcolas et al. 1997), relation to climate (Hüsken, Schirmer 1993; Strumia, Cherubini 1997), and larch budmoth outbreaks (Weber 1997, Weber 1999).

In the past decades several larch chronologies have been constructed in different parts of the Alps. Among the oldest published ones is the 645 years long larch chronology from Ötztal, Austria (Siebenlist-Kerner 1984). It is based on long-lived trees and local buildings and spans the period 1333-1974. Tessier (1986) presented the larch chronology from the French Alps going from 1353-1973. The chronology of Bebber (1990) is 1208 years long and spans the period 781-1988. Nola and Motta (1996) constructed a multicentury chronology of larch from the Valmalenco, Italy, spanning the period 1007-1994. In Austria in recent years the laboratories from Innsbruck and Vienna independently constructed two millenary larch chronologies, the chronology from Tyrol (Nicolussi 1995; Nicolussi, Lumasseger 1998) and the chronology from Dachstein (Gindl et al. 1998). The authors entrusted us the versions of their chronologies spanning 1243 and 1336 years respectively for comparisons in this study. Both laboratories continue to work to improve and extend the chronologies. Their collab-

Corresponding author: K. Čufar - Tel. ++386 1 4231161 - Fax ++386 1 4235035 - e-mail: katarina.cufar@uni-lj.si

orative work helped to extend the Dachstein chronology that currently spans 3474 years (Grabner et al. 2001) and is among the longest continuous tree-ring records in the Alpine region.

Long chronologies are particularly rare in the SE Alpine region. In Slovenia and NE Italy old trees can usually only be found on barely accessible locations. Near the forest stands it is very difficult to find old wooden constructions or sufficiently preserved stems of dead trees. On the other hand larch has often been used in the construction of important historic buildings in the towns on the Adriatic coast where it has remained well preserved over the centuries. Since there are no larch forest stands in the coastal region the timber for construction was imported. The nearest larch forest stands are located in the Slovenian and NE Italian Alps and several publications report on timber transport from there to the coastal region (e.g. Casti-Moreschi, Zolli 1988; Gestrin 1965; Pahor, Hajnal 1981).

The laboratories in Ljubljana, Slovenia, and Verona, Italy, needed a long regional chronology for dating, to study the origin of wood, and to interpret past environmental fluctuations. It seemed unlikely that it would be possible to construct such a chronology using only locally available wood, therefore a collaborative study was set up to construct a regional chronology.

The objective of this study is to present the construction of a regional larch chronology based on chronologies of trees and mean curves of historic buildings from Slovenia and NE Italy as well as to compare it with available alpine larch chronologies from nearby regions.

Materials and Methods

The wood used to construct the chronology originated from living trees from larch forest stands in the Slovenian and Italian Julian Alps and from the Anterselva Valley in the Italian Alps (Fig. 1). In the SE Slovenian Julian Alps we selected 20 trees from the natural larch forest stands around the Bohinj lake at elevations 1500 - 1890 m. In the Italian Julian Alps we selected 10 trees growing at Sella di Lom near Tarvisio, Friuli, elevation 1435 m. In Alto Adige, we selected living trees from two sites in the Anterselva Valley. 12 trees were growing at elevations of 2090 m (ANT1) and 12 trees at 1700 m (ANT2).

The historic wood came from the remnants of the military buildings in the Julian Alps and the St. George's church in Piran (Slovenia), the church of Santa Maria Gloriosa dei Frari and the Arsenal in Venice, and the patriarchal basilica from Aquileia (Italy) (Fig. 1).

The remnants of the military buildings from World War I were located in the SE Julian Alps, near the investigated forest stands. The buildings were abandoned and are now in ruins.

All other buildings are located in towns on the Adriatic coast. The timber used in constructions was imported but its exact origin is not known. St. George's church in Piran is a complex building reconstructed from the former romanic, gothic, and baroque churches. Numerous signs of reuse indicate that the timber of the roof construction originates from different time periods. The church Santa Maria Gloriosa dei Frari in Venice is also a typical complex building with several different building phases. The Arsenal in Venice is a vast assemblage of basins, yards, and workshops for shipbuilding built in the 16th century. It occupies a whole sector in the north east of the city and was, until the 18th century, Europe's largest industrial complex. The patriarchal Basilica in Aquileia was first built in 313 AD and then destroyed and rebuilt several times. The building also contains several different building phases.

The wood from the trees was collected by taking two cores per tree at breast height. The wood from the buildings was mainly taken from the roof constructions by coring. Our plan was to take cores or wood samples from at least 5-10 elements of each of the presumed building phase. The number of cores varied from building to building because the sampling was severely limited by availability and condition of timber.

In the World War I ruins we took a total of 13 samples from the sufficiently preserved beams of two buildings. In St. George's church we took 88 cores from different parts and phases of the roof construction. In Frari we collected cores from 36 trusses in the roof construction of the main building.

In Arsenal we collected samples from 47 trusses of the roof construction of different buildings. In the basilica of Aquileia we collected cores from 17 elements of the roof construction and the ceiling. The timber elements were always examined for carpentry signs, signs of re-use, as well as presence of sapwood, the last ring below the bark (*Waldkante*), and presence of the bark. The wood identification was performed in accordance with standard wood anatomical procedures (e.g. Schweingruber 1982).

The wood was smoothed and the tree-rings were measured to the nearest 0.01 mm. The CATRAS and TSAP/X programmes were used for data acquisition and processing. Individual tree-ring series were visually and statistically cross-dated and compared with each other by calculating the "Gleichläufigkeit" (GLK%) coefficient (Eckstein, Bauch 1969), the t-value (tBP) after Baillie and Pilcher (1973), and the period of overlapping. The local chronologies of trees and mean curves of the buildings were constructed using standard dendrochronological methods and compared with each other. Finally a chronology IT-SLO1 was built by joining the local chronologies and mean curves. The statistical parameters of the chronology were calculated by using TSAP/X and standard statistical programmes.

IT-SLO1 was compared with larch chronologies from the east Italian Alps (Bebber 1990), Ötztal, Tyrol, Austria (Siebenlist-Kerner 1984), Tyrol, Austria (Nicolussi 1995 and pers. comm.), and Dachstein, Austria (Gindl et al. 1998 and pers. comm.). Fig. 1 presents their location regarding our sampling areas.

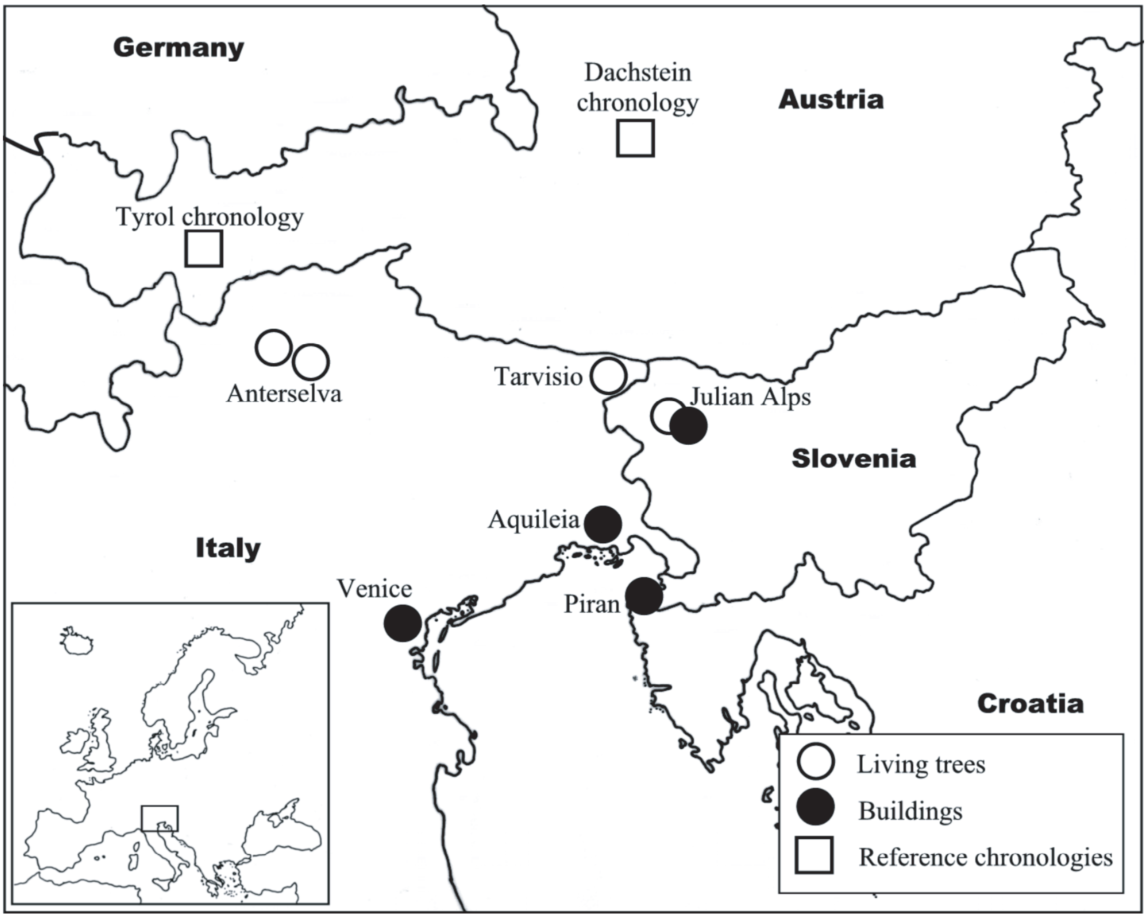

Fig. 1 - Locations of forest sites, and buildings providing the wood to construct the regional chronology IT-SLO1 and locations of reference chronologies used for comparison.

Code	Location	Altitude	Length	Date Begin	Date End	Replication
JUL	Julian Alps (Slo)	1500 - 1890	518	1480	1997	19
ANT1	Anterselva (It)	2090	269	1727	1995	12
ANT2	Anterselva (It)	1700	175	1821	1995	12
TARV	Tarvisio (It)	1435	142	1854	1995	10

Tab. 1 - Code, location, date span, and maximum replication of the local chronologies. The chronologies ANT1, ANT2, and TARV are based on trees, the JUL1 is based on trees and timber from the local constructions.

Results and Discussion

Local chronologies

We constructed four local chronologies based on living trees from four different locations. The basic data on these chronologies are presented in Tab. 1 and Fig. 2.

The longest local chronology is the one from the SE Julian Alps, Slovenia. It is 518 years long and covers the period 1480 – 1997. It is based on the chronology from living trees extended by the mean curves from the nearby military buildings. The local chronology of Tarvisio is 142 years long and covers the period 1854-1995. The chronology from the higher elevations of the Anterselva Valley (ANT1) covers the period 1727-1995, and the one from lower elevations (ANT2) the period 1821-1995.

The overlapping of local chronologies is shown in Fig. 2, the results of their cross-dating in Tab. 3, and the visual agreement of their tree-ring indices in Fig. 3. The Julian Alps chronology (JUL) cross-matched better with both distant chronologies of Anterselva (ANT1 and 2) than with the nearby one from Tarvisio (TARV). This confirms good teleconnection of larch over relatively long distances in the region and indicates influence of elevation on ring patterns.

Mean curves of the buildings

The samples of timber from the constructions enabled us to construct five fairly well replicated mean curves containing only those tree-ring series that showed the best visual and statistical agree-

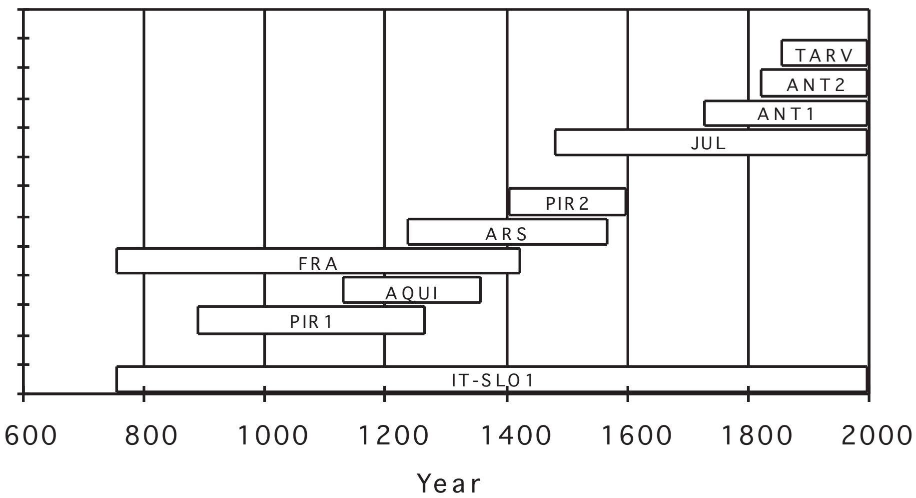

Fig. 2 - Time spans and overlapping of chronologies and mean curves used to construct a regional chronology IT-SLO1. For chronology codes see Tabs. 1 and 2.

Code	Building, Location	Length	Date Begin	Date End	Replication
PIR2	St. George's Church, Piran (Slo)	189	1405	1593	12
ARS	Arsenal, Venice (It)	329	1236	1564	15
FRA	Frari Church, Venice (It)	665	756	1420	15
AQUI	Patriarchal Basilica, Aquileia (It)	225	1131	1355	6
PIR1	St. George's Church, Piran (Slo)	375	890	1264	10

Tab. 2 - Code, location, date span, and maximum replication of the mean curves of buildings.

ment. Two mean curves were constructed for St. George's church in Piran. PIR1 is 375 years long, whilst PIR2 is 189 years long. The mean curves of Arsenal and Frari church in Venice are 329 and 665 years long. The mean curve of the patriarchal basilica in Aquileia is 225 years long. Their overlapping, length and maximum replication are presented in Tab. 2 and Fig. 2.

The mean curves of buildings were compared with each other and with local chronologies. The cross-dating parameters presented in Tab. 3 show significant cross-matching between all overlapping chronologies and mean curves. Piran 2 (PIR2) and Arsenal (ARS) were cross-dated with the chronology of the Julian Alps (JUL). The GLK% was 77*** and 68*** and the t_{BP} 7.3 and 6.3 respectively. The cross-matching of the mean curves from the buildings was particularly high between Piran 2 and Arsenal (GLK%=76***, t_{BP}=13.7) (Fig. 4) and Piran 1 and Frari (GLK%=74***, t_{BP}=15.5), although in both cases the buildings are located in towns that are more than 100 km apart. This could indicate that the wood originated from the same location or similar altitude.

The construction of the regional chronology and its comparison with other chronologies

The presented local chronologies and mean curves were used to construct the regional chronology IT-SLO1 that is 1242 years long and spans the period 756-1997. Tab. 4 presents the statistical parameters of the chronology. Its replication is fairly good with mean density 17 (6 - 31). Only the oldest part 756-911 is based on 1-3 samples only (Fig. 5).

The results of comparisons with available alpine larch chronologies are presented in Tab. 5. The agreement of tree-ring patterns was most significant when IT-SLO1 was compared with chronologies from Dachstein (Gindl et al. 1998) and Tyrol (Nicolussi 1995). The values were lower when IT-SLO1 was compared with the Ötztal chronology of Siebenlist-Kerner (1984) and the NE Italian Alps chronology of Bebber (1990). The visual inspection of agreement between the IT-SLO1 and the chronology of the NE Italian Alps indicated that the former

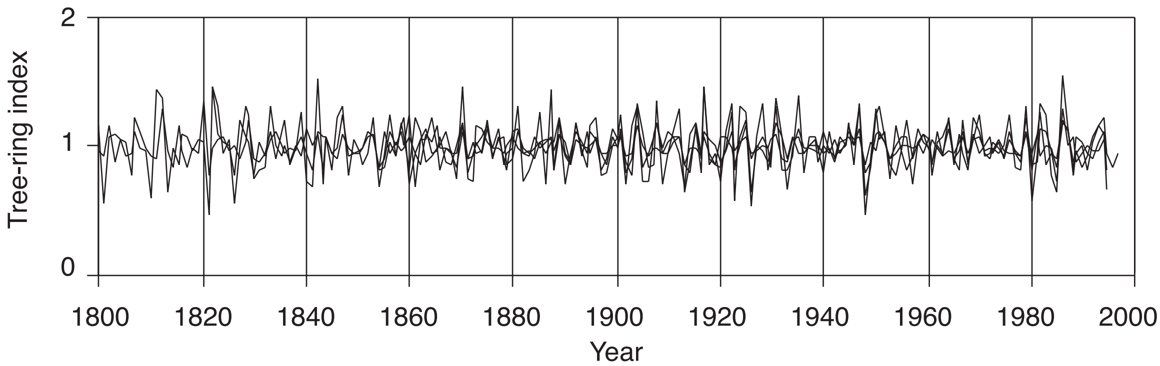

Fig. 3 - Indexed values of overlapping chronologies JUL, ANT1, ANT2 and TARV. See also Tabs. 1 and 3 and Fig. 2.

	JUL	ANT1	ANT2	ARS	FRA	AQUI
ANT1	8.1					
ANT2	8.5	8.9				
TARV	6.0	5.5	4.8			
PIR2	7.3			13.7		
ARS	6.3					
FRA				6.8		
AQUI				4.4	9.4	
PIR1					15.5	7.7

A) t_{BP}-value after Baillie and Pilcher, values above 4.0 are statistically significant, minimum overlap was 85 years between ARS and JUL.

	JUL	ANT1	ANT2	ARS	FRA	AQUI
ANT1	60***					
ANT2	68***	70***				
TARV	62***	56	64***			
PIR2	77***			76***		
ARS	68***					
FRA				69***		
AQUI				62***	73***	
PIR1					74***	66***

B) GLK% - "Gleichläufigkeit"; *** stars indicate statistical significance level of 99.9%.

	JUL	ANT1	ANT2	ARS	FRA	AQUI
ANT1	269					
ANT2	175	175				
TARV	142	142	142			
PIR2	114			160		
ARS	85					
FRA				185		
AQUI				120	225	
PIR1					375	134

C) Overlap of chronologies and mean curves (in years).

Tab. 3 - Cross-dating parameters of overlapping chronologies and mean curves. For chronology codes see Tabs. 1 and 2.

supposedly had two excessive rings in its poorly replicated part between 1370 and 1390. This observation is in agreement with that of Nicolussi (1995), Nola and Motta (1996), as well as Carrer, Friedrich, Spurk, and Urbinati (pers. comm.). When we deleted two supposedly excessive rings and compared the "corrected" NE Italian Alps chronology with IT-SLO1 and other reference chronologies we obtained a far more significant agreement.

Based on the results presented we can confirm a good teleconnection of larch in the Alpine region which was also observed by Nola and Motta (1996), Urbinati and Carrer (1996), and Carrer (1997) for different locations in the Alps.

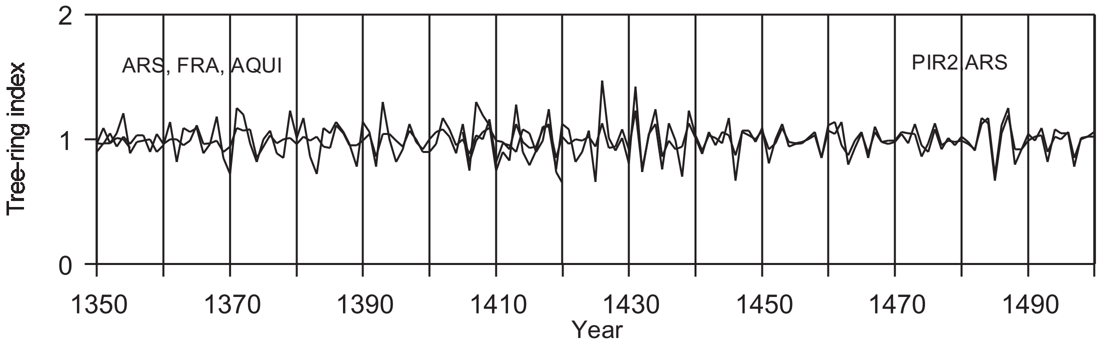

Fig. 4 - Indexed values of overlapping chronologies ARS, FRA, AQUI, and PIR2. See also Tabs. 2 - 3 and Fig. 2.

Conclusions

A 1242 years long regional larch chronology spanning the period of 756-1997 has been built. It currently represents the longest continuous and sufficiently replicated tree-ring record based on wood from Slovenia and NE Italy and is among the longest chronologies in the region south of the Alps. The chronology proved to be of great value for dating wood from the historical objects. It has great potential to be used to interpret past events in the region, to obtain more information on timber trade, and to study influence of climate changes on tree growth. Its cross-dating with reference chronologies from regions north of the sampling area confirms a good teleconnection of larch.

IT-SLO1	
Length	1242 years
Time Span	756 - 1997 AD
Mean sample density	17
Average ring width (mm)	0.92
Minimum ring width (mm)	0.26
Maximum ring width (mm)	4.21
Variance	0.16
Standard Deviation	0.40
1st order autocorrelation	0.86
Mean Sensitivity (%)	17
Relative Mean Sensitivity (%)	18
Tendency Change (%)	62

Tab. 4 - Statistical parameters of the regional chronology IT-SLO1.

Acknowledgements

The work in Slovenia was funded by the Ministry of Science and Technology of the Republic Slovenia, Project J4-7434, and the Restoration Centre of the Republic Slovenia. The Italian alpine chronologies are based on material from the study "Rapporto ENEL/CRAM n.1997/0168. Studio sui limiti superiori della vegetazione d'alta quota. Studio sugli accrescimenti degli alberi quali indicatori dell'incremento di CO_2 e modificazioni

Reference Chronology	Authors	Time Span	GLK%	t_{BP}	Overlap
NE Italian Alps	Bebber 1990	781-1988	60***	8.1	1209
NE Italian Alps	Bebber 1990 corrected	783-1988	72***	24.7	1207
Tyrol, Austria	Nicolussi 1995	750-1992	71***	22.1	1237
Dachstein, Austria	Gindl et al. 1998	663-1998	70***	25.0	1242
Ötztal, Austria	Siebenlist-Kerner 1984	1330-1974	70***	16.2	645

Tab. 5 - Comparison of the regional chronology IT-SLO1 (756-1997) with other long alpine larch chronologies. (GLK% - Gleichläufigkeit (%) with significance level, t_{BP} - t-value after Baillie and Pilcher).

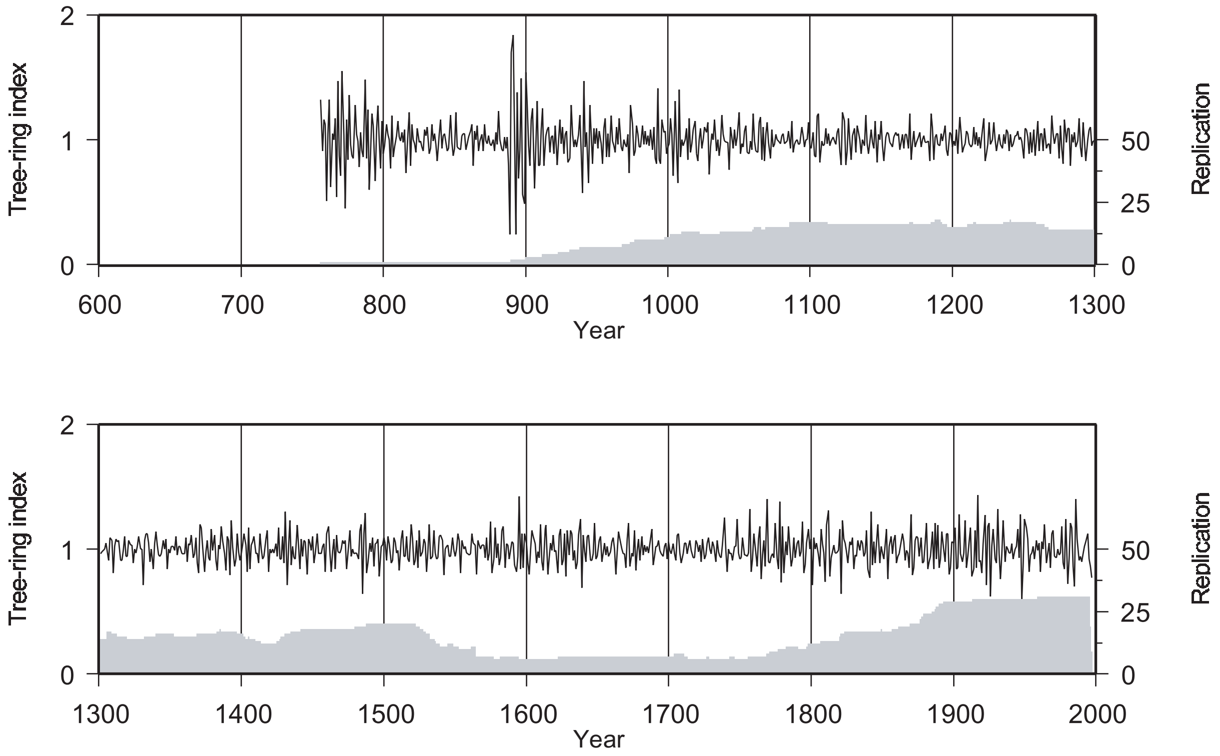

Fig. 5 - Indexed values of the chronology IT-SLO1 and its replication. Compare also Fig. 2.

climatiche Indagini dendrocronologiche su siti alpini." We thank ENEL for kindly allowing us to use the data for the present study. The dendrochronological investigations in the patriarchal basilica in Aquileia were conducted by Dendrodata s.a.s. on demand of the Soprintendenza per i Beni Ambientali, Architettonici, Archeologici, Artistici e Storici del Friuli-Venezia Giulia. The research in the church Santa Maria Gloriosa dei Frari and Arsenal in Venice were carried out by Dendrodata s.a.s. on demand of Soprintendenza per i Beni Ambientali Architettonici di Venezia. We are grateful to the Soprintendenza per i B.A.A.A.A.S. del Friuli – Venezia Giulia and to the Soprintendenza per i Beni Ambientali e Architettonici di Venezia for kindly allowing us to present the data in our work.

We are thankful to Kurt Nicolussi from Innsbruck, Austria and Michael Grabner from Vienna, Austria for entrusting us their larch chronologies for comparison, to Cathy Groves for reading and commenting on the manuscript, and to anonymous reviewers for their suggestions to improve the article.

References

Baillie MGL, Pilcher JR, 1973. A simple cross-dating programme for tree-ring research. Tree-Ring Bulletin, 33: 7-14.

Bebber AE, 1990. Una chronologia del larice (*Larix decidua* Mill.) delle Alpi orientale italiane. Dendrochronologia, 8: 119-140.

Belingard C, Tessier L, 1993. Etude dendroecologique comparee de vieux peuplements de *Larix decidua* Mill. dans les Alpes Francaises du sud. Dendrochronologia, 11: 69-78.

Carrer M, 1997. Analisi dendroecologica e della struttura spaziale in una cenosi forestale del limite superiore nelle Alpi orientali. PhD Thesis in Forest Ecology, University of Padova, 132 pp.

Casti Moreschi E, Zolli E, 1988. Boschi della Serenissima. Dal passato a noi. Strumenti didattici - 2, Venezia, 133 pp.

Eckstein D, Bauch J, 1969. Beitrag zur Rationalisierung eines dendrochronologischen Verfahrens und zur Analyse seiner Aussagesicherheit. Forstwissenschaftliches Centralblatt, 88: 230-250.

Gassmann P, Sester L, Perrot J, 2000. L'arbre à histoires. Salamander, 141: 1-51.

Gestrin F, 1965. Trgovina slovenskega zaledja s primorskimi mesti od 13. do konca 16. stoletja. SAZU

Ljubljana, 295 pp.

Gindl W, Strumia G, Grabner M, 1998. Dendroklimatologische Rekonstruktion der Sommertemperatur am östlichen Dachsteinplateau während der letzten 800 Jahre. Mitteilungen der ANISA 19/20: 24-28.

Grabner M, Wimmer R, Gindl W, Nicolussi K, 2001. A 3474-year alpine tree-ring record from the Dachstein, Austria. Tree Rings and People, International Conference on the Future of Dendrochronology, Davos: 252-253.

Hüsken W, Schirmer W, 1993. Drei Jahrringchronologien aus den Pragser Dolomiten/Südtirol). Dendrochronologia, 11: 123-137.

Levanič T, Čufar K, Hudolin J, Benko-Mächtig B, 1997. Dendrokronoloska analiza stresne konstrukcije zupne cerkve sv. Jurija v Piranu. Annales, 10: 43-52.

Motta R, Masarin F, 1996. Strutture e dinamiche forestali di popolamenti misti di pino cembro (*Pinus cembra* L.) e larice (*Larix decidua* Miller) in Alta Valle Varaita (Cuneo Piemonte). Archivo Geobotanico, 2 (2): 123-132.

Motta R, Nola P, Piussi P, 1999. Structure and stand development in a mixed Norway spruce (*Picea abies* (L.) Karst.), larch (*Larix decidua* Mill.) and stone pine (*Pinus cembra* L.) stand in Paneveggio (Trento, Italy). Dendrochronologia, 16-17: 57-73.

Nicolussi K, 1995. Dendrochronologische Untersuchungen zur mittelaterlichen Baugeschichte von Schloss Tirol. Tiroler Heimat, 59: 19-43.

Nicolussi K, Lumassegger G, 1998. Tree ring growth of Pinus cembra at the timberline in the central Eastern Alps: preliminary results. Institut für Hochgebirgsforschung – Jahresbericht 1997: 48-53.

Nola P, 1994. A Dendroecological study of Larch at timberline in the Central Italian Alps, Dendrochronologia, 12: 77-91.

Nola P, Motta R, 1996. Una cronologia plurisecolare di larice (*Larix decidua* Mill.) per l'Alta Valmalenco (Sondrio, Italia). Dendrochronologia, 14: 31-42.

Pahor M, Hajnal I, 1981. Po jamborni cesti v mesto na Peklu. Presernova Druzba Ljubljana, 266 pp.

Petitcolas V, Rolland C, Michalet R, 1997. Tree-growth of spruce, larch, arolla pine and mountain pine near the timberline in four French alpine areas. Annales des sciences forestieres, 54(8): 731-745.

Schweingruber H, 1982. Mikroskopische Holzanatomie. Kommissionsverlag F. Flück-Wirth, Internationale Buchhandlung für Botanik und Naturwissenschaften, Taufen. 2nd ed., 226 pp.

Schweingruber H, 1992. Baum und Holz in der Dendrocrhonologie. Eidgenössische Forschung-sanstalt für Wald, Schnee und Landschaft, 2nd ed., 231 pp.

Siebenlist-Kerner V, 1984. Der Aufbau von Jahrringchronologien für Zierbelkiefer, Lärche und Fichte eines Alpinen Hochgebirhsstandortes. Dendrochronologia, 2: 9-29.

Strumia G, Cherubini P, 1997. Il segnale climatico di due cronologie plurisecolari di larice (*Larix decidua* Mill.) delle Alpi Italiane. Dendrochronologia, 15: 171-179.

Tessier L, 1986. Chronologie de melezes des Alpes et petit age glaciaire. Dendrochronologia, 4: 97-113.

Urbinati C, Carrer M, 1996. Recent dynamics of an alpine timberline forest in the Italian Estern Alps. In Bergeron Y and Frisque G (Eds), Proc. Second International Workshop on Disturbances Dynamics in Boreal Forest, Rouyn-Noranda, Quebec, Canada: 247-252.

Weber UM, 1999. Auf den Spuren der Lärchenwickler - Was Jahrringe von Insekten und Klima erzählen. Bauhinia, 13: 15-28.

Weber UM, 1997. Dendroecological reconstruction and interpretation of larch budmoth (*Zeiraphera diniana*) outbreaks in two central alpine valleys of Switzerland from 1470-1990. Trees, 11: 277-290.