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Cover image: embankments at the Danube waterfront of Regensburg "Donaumarkt" made of re-used Roman material, probably Carolingian (S. Codreanu-Windauer, BLfD 2014).

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research

Medieval inland navigation and the shifting fluvial landscape between Rhine and Danube (Germany)

LUKAS WERTHER*
LARS KRÖGER**

* Friedrich-Schiller-Universität Jena, Löbdergraben 24a, D-07743 Jena, Germany. Corresponding author: *lukas.werther@uni-jena.de*
** Deutsches Schiffahrtsmuseum, Leibniz-Institut für deutsche Schifffahrtsgeschichte, Hans-Scharoun-Platz 1, D-27568 Bremerhaven, Germany.

Post-classical inland navigation and fluvial infrastructure between Rhine and Danube has been a pivotal point of research in the last decade. The aim of the paper is to overview the complex interplay and development between groups using and transforming rivers for different purposes as well as transported goods, legal frameworks, riverine vessels, harbours and river crossings. Based on archaeological, historical and geographical sources, structural changes of navigation from antique pre-conditions to the later Middle Ages will be discussed.
Keywords: southern Germany, inland navigation, fluvial landscapes, infrastructure, Middle Ages

La navigazione interna e le infrastrutture fluviali post-classiche tra Reno e Danubio sono state un cruciale argomento di ricerca negli ultimi dieci anni. Questo articolo si propone di offrire una panoramica della complessa interazione e dello sviluppo tra gruppi che usavano e trasformavano i fiumi per differenti motivi, delle merci trasportate, della cornice giuridica, delle imbarcazioni fluviali, delle darsene e degli attraversamenti fluviali. Sulla base delle fonti archeologiche, storiche e geografiche, verranno discussi i cambiamenti nella navigazione dall'antichità fino al Basso Medioevo.
Parole chiave: *Germania meridionale, navigazione interna, paesaggi fluviali, infrastrutture, Medioevo*

1. Introductory remarks

Focusing on the 6th to 13th century AD, this study highlights post-classical inland navigation and the use of shifting fluvial landscapes in Southern Germany. We discuss the topic for the rivers Main and upper Danube with their important tributaries and some outlooks on the Upper Rhine. This study area (fig. 1) is framed by the antique and medieval cen-

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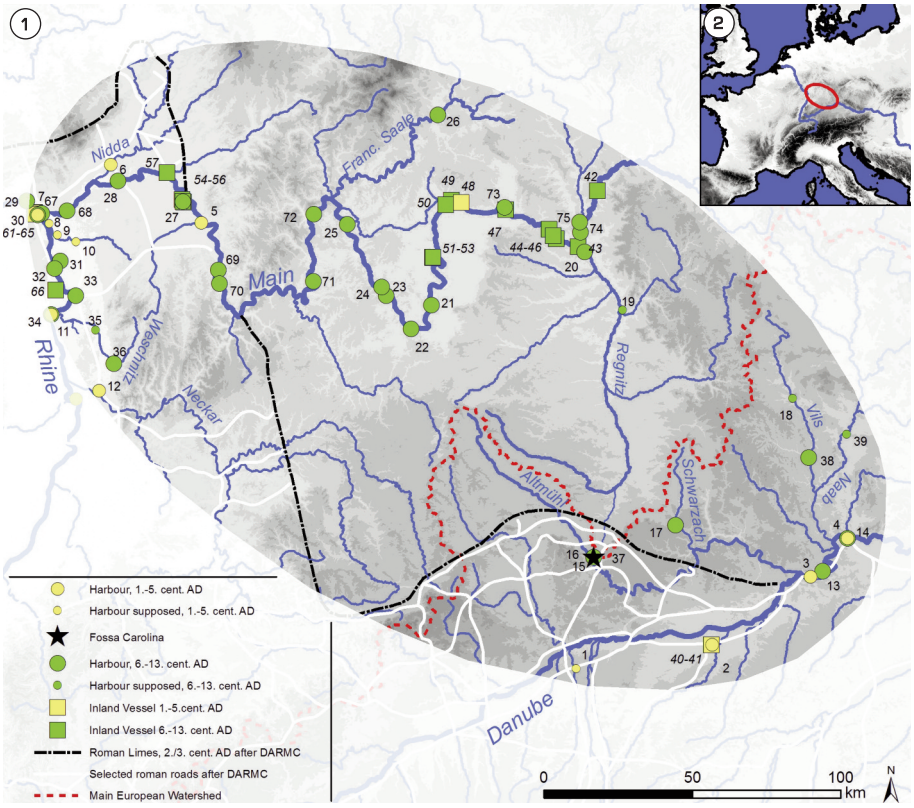

Fig. 1. 1: General map of harbours and vessels proofed by archaeological and written sources at selected rivers between Mainz and Regensburg (1st-13th century AD, status 2016). All numbers refer to the tables in figs. 2, 3, 5 and 11. The higher density along the river Main is caused by the systematic collection of ferry harbours only in this part of the study area. 2: Location of the study area in Europe (map data SRTM-GDEM © NASA 2009, CCM River and Catchment Database © European Commission 2007).

ters and traffic junctions Mainz and Regensburg. They form the two edges of a transport axis which connects the hydrological systems of Rhine and Danube by bridging the main European watershed.

Nevertheless, rivers are not only connecting but also dividing features, representing borders and obstacles, favorable routes, sources of energy and resources as well as permanent danger at the same time for those living at the waterfront, navigating or crossing them (Squatriti 2000; Bütow 2011; Edgeworth 2011; Campbell 2012; Franconi 2016). On a large scale, the hydrological system is stable over millennia, but on a micro-scale the complex interplay of natural dynamics and anthro-

pogenic influence resulted in shifting fluvial landscapes – and therefore highly dynamic conditions for inland navigation (Ellmers 2007, pp. 163-164; Schirmer 2007; Dambeck *et al.* 2008; Wawrzinek 2009; Hoffmann *et al.* 2010; Edegworth 2011; Roggenkamp, Herget 2014; Franconi 2016; Werther 2016).

There are three main reasons to use rivers for navigation despite of all problems: the often (but not always, see Bütow 2011, pp. 21-22) cheaper, faster or more comfortable transport compared to terrestrial routes, the need to cross rivers and the use of specific aquatic resources by boat.

2. Roman pre-conditions for medieval navigation between Rhine and Danube, 1st–5th century AD

In the Roman period, the *limes* divided the study area in regions with and without Roman infrastructure for inland navigation. For a certain period, Main and Danube have been used as borders, too. Between these borders, most of the fluvial axis bridging the main European watershed between Rhine and Danube was located in the *barbaricum* and roads from the upper Danube to the Rhine-Neckar area connected the separated (fig. 1) harbour networks (Kemkes 2005; Steidl *et al.* 2008, pp. 14-48; Preiser-Kapeller, Werther in press).

From the 1st century AD onwards, the Roman military as well as civilian ship-owner navigate the rivers inside (and sometimes outside) the *limes*. Besides the fast transportation of troops, the easy distribution of bulk goods especially downstream made ships an essential means of transportation (Marlière 2001; Höckmann 2003a; Fischer 2007, p. 98; Konen 2008; Steidl *et al.* 2008, pp. 27-129; Weski 2009; Himmler 2011; Schmidts 2011; Campbell 2012, pp. 291-329; Domínguez-Delmás *et al.* 2014; Kulovits 2014; Franconi 2016). With the Roman expansion, complex planked vessels – fast military boats as well as heavy-load cargo ships – have been introduced to southern Germany, as shipwrecks (figs. 2, 4) from Oberstimm and Mainz document (Bockius 2002, 2003, 2006).

In important riverine centres such as Mainz/*Mogontiacum* (Höckmann 2003b; Wawrzinek 2014, pp. 312-314) and Augsburg/*Augusta Vindelicum* (Wawrzinek 2014, pp. 227-228), complex wooden harbour constructions (fig. 3) with quays, piers and perhaps even artificial basins have been excavated, sometimes connected with shipwrecks (Bockius 2006). A masonry quay wall in Stockstadt at the Main waterfront gives

Number on map	Name	River	Construction	Dating (d: dendrodated)	Reference
40	Oberstimm 1	Sandrach	keel boat	ca. 110d	Bockius 2002
41	Oberstimm 2	Sandrach	keel boat	ca. 110d	Bockius 2002
42	Ebensfeld, EN 61	Main	logboat	ca. 1235d	Katalog Kröger in prep. EN-61
43	Bamberg, EN 2	Main	logboat	after 1123d	Katalog Kröger in prep. EN-2
44	Stettfeld, EN 36	Main	logboat	after 824d	Katalog Kröger in prep. EN-36
45	Staffelbach, EN 81	Main	logboat	ca. 1170d	Katalog Kröger in prep. EN-81
46	Viereth, EN 93	Main	logboat	after 1157d	Katalog Kröger in prep. EN-93
47	Mariaburghausen, EN 97	Main	logboat	after 606d	Katalog Kröger in prep. EN-97
48	Schonungen, EN 32	Main	logboat	after 80d	Katalog Kröger in prep. EN-32
49	Schweinfurt, EN 33	Main	logboat	1207/1208d	Katalog Kröger in prep. EN-33
50	Schweinfurt, EN 80	Main	logboat	ca. 1268d	Katalog Kröger in prep. EN-80
51	Obereisenheim, EN 99	Main	logboat	after 1208d	Katalog Kröger in prep. EN-99
52	Obereisenheim, EN 100	Main	logboat	after 1247d	Katalog Kröger in prep. EN-100
53	Obereisenheim, EN 101	Main	logboat	after 1218d	Katalog Kröger in prep. EN-101
54	Seligenstadt, EN 28	Main	logboat	after 1121d	Katalog Kröger in prep. EN-28
55	Seligenstadt, EN 29	Main	logboat	after 1048d/1242d	Katalog Kröger in prep. EN-29
56	around Seligenstadt, EN 31	Main	logboat	after 1085d/1220d	Katalog Kröger in prep. EN-31
57	Steinheim, EN 109	Main	logboat	after 1284d	Katalog Kröger in prep. EN-109
58	Mainz 1	Rhine	logboat	377d	Bockius 2006
59	Mainz 2	Rhine	logboat	after 287d	Bockius 2006
60	Mainz 3	Rhine	logboat	255d	Bockius 2006
61	Mainz 4	Rhine	logboat	393d	Bockius 2006
62	Mainz 5	Rhine	logboat	385d	Bockius 2006
63	Mainz 6	Rhine	flat-bottomed boat	81d	Pferdehirt 2002
64	Mainz 7	Rhine	flat-bottomed boat	presumably ca. 75	Pferdehirt 2002
65	Mainz S8	Rhine	logboat	after 431d	Bockius 2006
66	Gimbsheim	Rhine	flat-bottomed boat	ca. 760d	Höckmann 1997

Fig. 2. Compilation of vessels (1st-13th century AD) at selected rivers between Mainz and Regensburg, mapped in fig. 1 (data collection: L. Kröger).

Number on map	Name	River	Written sources for the harbour	Archaeol. sources for the harbour	Dating (d: dendrodated)	Reference
1	Burghöfe	Danube	assumed		4th/5th cent. assumed	Wawrzinek 2014, Katalog B Höckmann 2003a
2	Oberstimm	Brautlach		yes	1st/2nd cent. d	Wawrzinek 2014, Katalog A Weski 2010 Höckmann 2003a
3	Untersaal	Danube		assumed	4th/5th cent. assumed	Wawrzinek 2014, Katalog A Czysz *et al.* 2005
4	Regensburg	Danube	assumed	assumed	from 1st cent. assumed, continuous use to the Middle Ages very likely	Wawrzinek 2014, Katalog A Weski 2010
5	Stockstadt	Main		yes	2nd/3rd cent. assumed	Wawrzinek 2014, Katalog A Weski 2010 Steidl *et al.* 2008
6	Nida-Heddernheim	Nidda		yes	2nd/3rd cent. assumed	Wawrzinek 2014, Katalog A Steidl *et al.* 2008
7	Mainz	Rhine	yes	yes	from 1st cent. d, continuous use to the Middle Ages	Wawrzinek 2014, Katalog A
8	Ginsheim	Schwarzbach		assumed	roman	Wawrzinek 2014, Katalog B
9	Trebur-Astheim	Schwarzbach		yes	4th/5th cent., continuous use to the Middle Ages assumed	Wawrzinek 2014, Katalog B Heising 2012
10	Groß-Gerau	Altneckar		assumed	roman, from 1st cent. assumed	Wawrzinek 2014, Katalog B
11	Zullestein	Weschnitz / Rhein		yes	4th/5th cent., continuous use to the Middle Ages assumed	Wawrzinek 2014, Katalog A Heising 2012 Jorns 1979
12	Ladenburg	Neckar		assumed	4th cent.	Wawrzinek 2014, Katalog A

Fig. 3. Compilation of roman harbours (1st-5th century AD) at selected rivers between Mainz and Regensburg (based on Wawrzinek 2014).

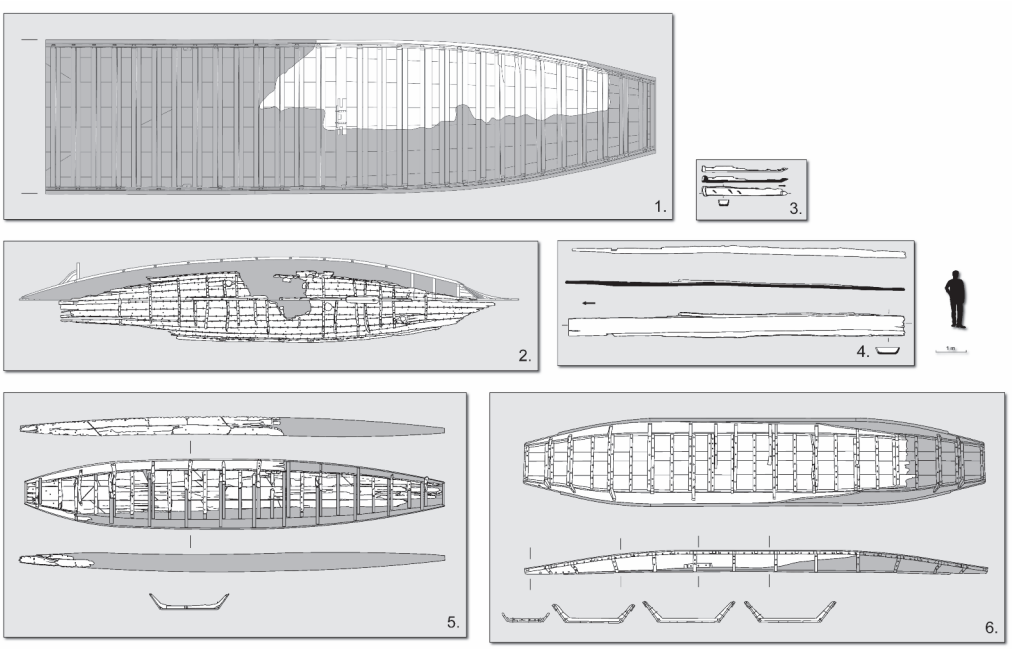

Fig. 4. Selected vessels of the 1st-13th century AD, dark grey: reconstructed parts. 1: Mainz 6, dating 81 AD (reduced on the front part). 2: Oberstimm 2, dating around 118 AD. 3: Mariaburghausen, dating after 596d. 4: Stettfeld, dating after 824d. 5: Kalkar-Niedermörmter, dating around 802d. 6: Krefeld-Gelleg III, dating in the 8th century based on small finds (drawings L. Kröger after Bockius 2002; Pferdehirt 2002, p. 101; Kröger 2014, pp. 96 and 99; Kröger in press).

proof for more solid stone constructions. Nevertheless, simple landing sites with stone pavements (Nida-Heddernheim, Zullestein, Trebur-Astheim) or wooden bank reinforcements of different complexity (Oberstimm, Untersaal) have been the most widespread construction (Jorns 1979; Bockius 2002; Czysz *et al.* 2005, p. 526; Steidl *et al.* 2008; Weski 2010, p. 23; Heising 2012; Kulovits 2014, pp. 51-63; Wawrzinek 2014, pp. 324-399).

Except of the river Main, which has been outside the *limes* after mid-3rd century, the bigger rivers have been used continuously until late Antiquity and – on a reduced level – also beyond. Descriptions of grain ships navigating the Danube in the 5th century according to the *Vita Sancti Severini* (Fischer 2007, p. 99; Kulovits 2014, pp. 14-15) as well as a 5th century shipwreck and early 6th century bank reinforcements at the Rhine in Mainz give proof for that exemplarily (Bockius 2006; Wawrzinek 2014, p. 314).

3. People and purposes using waterways between Rhine and Danube

3.1. People and purposes using waterways, 6th-10th century AD

Specific sources for people using the waterways in the 6th-7th century are scarce, but the protection of river corridors with fortifications starting in the 7th century (Ettel 2015) and fluvial distribution patterns of Merovingian ceramics and glass indicate a certain importance of navigation (Koch 1996; Koch, Koch 1996, pp. 279-280; Ettel 2008). Nevertheless, it is not always clear if the river itself or terrestrial routes parallel to the river have been used for transportation (Dopsch 2012, p. 25; Steidl *et al.* 2008, pp. 74-112).

From the 8th century onwards more and more written sources specify passengers navigating the main rivers, but also small tributaries. Especially in the itineraries of Charlemagne and Louis the Pious there are many references for navigation upstream and downstream on Rhine, Main, Danube, Altmühl, Franconian Saale and Regnitz – and also for crossing the European watershed with ships dragging them overland (Dopsch 2012; Hack 2014; *Regesta Imperii* online RI I – Karolinger n. 307a, 320l, 320o, 832b, 899e, 1006b, 1955a; RI IV,2,1 – Lothar III. und ältere Staufer n. 65; RI IV,2,4 – Lothar III. und ältere Staufer n. 3265)[1].

The higher average speed of navigation downstream compared to terrestrial transport was a considerable motivation for the highly mobile elites of the Early Middle Ages (Reinke 1987, pp. 243-251; McKitterick 2008, pp. 181-186). It is debatable if navigation upstream, especially on small meandering rivers, was also faster than using roads (Bütow 2011), but it was more comfortable, which is also indicated in Carolingian sources (Hack 2014, pp. 54-61). Especially for those who were less mobile due to diseases or other reasons, the transport by boat was favorable (Pertz 1826, p. 362; Wagner 2007, p. 38; Hack 2009, pp. 231-253; *Regesta Imperii* online RI I – Karolinger n. 1955a).

The medieval royal "fluvial" itinerary was often part of military actions, especially on the Danube. In conflicts at the eastern periphery of the Carolingian and Ottonian empire, troops used the river for transportation frequently (e.g. *Regesta Imperii* online RI I – Karolinger n. 1490e u. 1955a; RI II,1 – Sächsisches Haus n. 238c; Freund 2007, pp. 51-52). In the 12th century the Danube was used by the crusaders, who departed from Regensburg to the Holy Land (Dopsch 2012; *Regesta Imperii*

[1] All *Regesta* mentioned in the article could be found following their number on the RI-homepage cited in the bibliography.

online RI IV, 1, 2 – Lothar III. und ältere Staufer n. 484; RI IV, 2, 4 – Lothar III. und ältere Staufer n. 3265).

Starting in the 8th century, orders highlight the attempt to improve the security of pilgrims and other groups navigating the rivers – but as descriptions of shipwrecks vividly show, this was not always successful (*Regesta Imperii* online RI I – Karolinger n. 302; Dopsch 2012, p. 25; Hack 2015).

In addition to secular elites, ecclesiastic groups were important users of waterways and ships from the Carolingian period onwards. Not only the transportation of passengers, but especially the distribution of the agricultural income of widespread possessions has been crucial in certain regions and periods (e.g. *Regesta Imperii* online RI I – Karolinger n. 1431; *Regesta Imperii* Regg. EB Mainz 1 n. 1; *Regesta Imperii* Regg. B Augsburg 1 n. 132; Johanek 1987; Adam 1996, pp. 181-183; Elmshäuser 2002; Haase *et al.* 2015).

The 9th century *Miracula Sancti Goaris* offer a vivid example, how even ecclesiastic elites have been personally engaged in the transportation of bulk goods on the river: according to the *Miracula*, an abbot from Cologne returned from the vintage on his possessions near Worms, shipping the Rhine downstream on a boat fully loaded with barrels, which ended in a shipwreck at St. Goar (Hack 2015, p. 194). For this period, the transport of wine from southern Germany downstream the Rhine is also proved by archaeological sources, as 8th century wine barrels made from Bavarian silver fir have been reused in Dorestad (Natris 2009). Furthermore, there are strong indications that even the construction wood for early medieval ships excavated in the Netherlands has been cut in the Rhine-Main area (Brouwers *et al.* 2015, pp. 13-14). Rhine, Main and Danube have been intensively used for cargo transport in this period and professional traders and ship-owner transported e.g. grain, salt and ceramic vessels (Johanek 1982; Johanek 1987, pp. 19-68; McCormick 2010, pp. 655-656; Hack 2015, pp. 193-202).

Nevertheless, the distribution pattern of Rhenish ceramics and other products like millstones clearly shows, that huge upstream sections of Rhine and Main and most tributaries like the Franconian Saale or the Regnitz have scarcely been integrated in this network (Losert 1993; Gross 2004; Ettel 2008; Gross 2009; Grunwald 2012; Werther 2012, p. 240; Werther 2015, pp. 36-37).

South of the European watershed similar structures have been observed, as ceramic wares typical along the Danube such as "Goldglimmerware" are very rare upstream of Kelheim and along the river Altmühl (Later 2015, p. 65). Nevertheless, it may not be a coincidence that one

of the exceptions in the Altmühl region with a bigger amount of "Goldglimmerware" is the Carolingian harbour of Großhöbing (Liebert 2015, pp. 260-270). Despite of the weak integration of upstream sections and tributaries in ceramic distribution, regularly navigation on the Altmühl in the Carolingian period is not only indicated by the royal itinerary (see above), but also by the 9th century *Vita Sualonis* describing the suitability of the river for merchant vessels (Holder-Egger 1887, p. 158; Eckoldt 1980, p. 72; Adam 1996, p. 91). The sources do not mention which cargo has been transported, but for several northern confluents of the Danube a relation to the flourishing iron production is very likely (Hensch 2013, pp. 274-294; Later 2013, pp. 318-320; Later 2015, pp. 44-46; Werther 2015, pp. 213-215).

The examples document clearly, that merchants and elites frequently used the rivers for navigation, but the everyday use of waterways and vessels beyond this small group is more difficult to describe. Short and medium-distance transports of agrarian products by boat have already been discussed (Haase *et al.* 2015). People running ferries are seldom documented before the 12th century in the study area (see below; Hägermann 1995, p. 169; Adam 1996, p. 158). 10th century documents regulating the legal framework of royal and private fisherman working on the river Main at Frankfurt exemplarily enlighten another group with a strong connection to everyday navigation (*Regesta Imperii* Online RI II, 3 – Sächsisches Haus n. 1113), but usually the early sources concerning fishery give no certain proof for navigation (Hägermann 1995; Matthäus 2004; Werther 2012, pp. 254). In rare occasions anthropological data offers another approach to everyday navigation; in a 8th-10th century graveyard at the confluence of Altmühl and Danube, several individuals had specific degenerative diseases that have been interpreted as aftereffects of rowing or punting vessels (Strott 2006, pp. 224-225).

In summary, the sources show clearly that at least on the main rivers of the study area, but also on some of the smaller tributaries, transportation of cargo and passengers by boat was very common in the Carolingian period (Adam 1996, pp. 31-180; McCormick 2010, pp. 655-656; Dopsch 2012, p. 25; Hack 2015; *Regesta Imperii* online RI I – Karolinger n. 2015a). An extraordinary detailed text, the late Carolingian *Inquisitio de theloneis Raffelstettensis*, enlightens the complex organization of navigation for a specific section of the Danube and how it was influenced by the fluvial conditions: whereas high tolls had to be paid for the easy transport downstream, navigation upstream against the current was cheaper or even free of charge (Adam 1996, pp. 123-124).

But not only the current significantly affected navigation: watersheds dividing the hydrological systems have been an even more influential obstacle (Werther *et al.* 2015; Zielhofer *et al.* 2014). It becomes more and more apparent, that neither the archaeological material nor the written sources give proof for a serious transportation of bulk goods between the systems of Rhine and Danube. The impression of two economic systems and navigational networks with only weak ties is also supported by the spectrum of Carolingian coins north and south of the watershed (Emmerig 2004; Coupland 2014). It seems like kings crossed the watershed more easily than cargo.

3.2. People and purposes using waterways, 11th-13th century AD

Ecclesiastical institutions participated actively in navigation in the 11th-13th centuries, too, many of them benefiting from water toll exemptions (Hägermann 1995; *Regesta Imperii* Regg. EB Mainz 1 n. 1008; *Regesta Imperii* Regg. EB Mainz 2 n. 378; *Regesta Imperii* online RI V, 1, 1 – Jüngere Staufer n. 285). A new and more and more dominating player in the transportation of cargo on the Rhine, Main and Danube are the flourishing urban centers. In this period, the participation of towns and citizens in navigation has been facilitated and often directly supported by royal initiatives (e.g. for Worms in 1074 *Regesta Imperii* Online RI III, 2, 3 – Salisches Haus n. 680; for Magdeburger in 1025 *Regesta Imperii* Online RI III,1 – Salisches Haus n. 18; Irsigler 1996; Bönnen 2010). Like for the Carolingian Danube, this support included specific regulations concerning the hydrological conditions: in 1157 Friedrich I. regulated the water tolls on the river Main, which had to be collected in Aschaffenburg, Neustadt and Frankfurt for all vessels going downstream, whereas all vessels going upstream have been free of charge (*Regesta Imperii* Online RI IV, 2, 1 – Lothar III. und ältere Staufer n. 447). Navigation has been highly political and also used for sanctions: to give an example, in 1121 the Mainz archbishop raised the harbour tolls in his town for merchants from Duisburg, who supported his opponent Heinrich V. (*Regesta Imperii* Regg. EB Mainz 1 n. 1473).

The increasing dependency of many growing towns on the riverine supply intensified conflicts like that. The building boom of the 12th and 13th centuries implicated the transportation of huge amounts of construction material such as wood and stone on the waterways (Steidl *et al.* 2008, pp. 228-258; Brouwers *et al.* 2015, pp. 13-14). This is documented clearly by many direct traces of rafted wood along the river Main in the 12th century and along the Danube in the early 13th century (Eißing, Dittmar 2011, pp. 138-143).

4. Vessels and navigation between Rhine and Danube

For the Roman period several shipwrecks (fig. 2) document the use of flat-bottomed and keel based vessels (see above). A fragment of a military rowing vessel from Mainz (S8) dated after 431 documents the late antique use of keel based vessels on the Rhine (fig. 2, no. 65; Bockius 2006, pp. 188-190). At the lower Danube, similar ships for military operations were still in use around 600 AD (Himmler 2011, pp. 150-156). Nevertheless, except of some late medieval and post-medieval vessels from the Main near Obereisenheim (Kröger 2013, pp. 118-126), from the Danube at Kehlheim (Herzig, Weski 2009) and from Mainz (Höckmann 1999) as well as several badly preserved bits and pieces of an early medieval boat from Gimbsheim at the river Rhein (fig. 2, no. 66; Höckmann 1997; Kröger 2014, pp. 95, 111) no planked vessels of the 6th-13th century AD have been documented yet in the study area.

But even if the archaeological material is quite limited, it is very likely that planked vessels have been used in this period between Rhine and Danube. It is a general phenomenon, that medieval logboats have been found almost all over Germany, but planked vessels are only known at the lower Rhine, around Bremen and in Schleswig-Holstein – natural factors and formation processes seem to be more important for this distribution pattern than the actual use of the different construction types in the medieval period (Kröger 2014). The excavated early medieval planked vessels are very similar to antique flat-bottomed cargo vessels, the so-called "Prahme", concerning their function, their general hull design and their construction except of some details – but their sizes are clearly reduced (cf. Kröger 2014). This is best documented by the almost completely preserved vessels from Krefeld-Gellep III with its loading capacity of almost 7 tons (fig. 4; Pirling, Buchwald 1974; Kröger in press), Kalkar-Niedermörmter (fig. 4; Kröger in press) at the Rhine and the "Karl" of Bremen at the Weser (Hoffmann, Ellmers 1990, pp. 33-34; Mücke 2011, pp. 36-44). The finds from Krefeld and Bremen have preserved mast steps, so they could have been not only punted, but also towed upstream. Especially for smaller vessels and slow currents, punting is an effective alternative to towing.

Due to their shallow and light construction early medieval boats could easily land on flat riverbanks without the need of solid installations which allow to moor afloat. To join the side and bottom planks a L-shaped transition plank in the floor section was used. This enabled a direct linking of the side planks with the massive floor planks and the construction got an enhanced stability, so fewer frames and therefore fewer curved grown wooden parts were needed. The disadvantage is the need of a whole

trunk for every transition plank. This construction technique disappears at the end of the middle ages and butt joints came into practice (see for example Höckmann 1999; Schletter 2012).

A special group, planked representative vessels used by the elites, are documented in contemporary iconographic (Dufrenne, Villain-Gandossi 1984) or written sources (see below), but no wrecks have been found yet. Vessels have also been used as floaters for heavy loads like ship mills and pontoon bridges, which is documented as early as 792 for the Danube (Kröger 2014, p. 111; Hardt 2007, pp. 108-109).

In contrast to the very limited number of planked vessels from the study area, there are several logboats from the 6th-13th centuries AD. Of special interest is an approximately 14 m long example from Stettfeld at the river Main. The vessel dated after 824 AD had an enormous loading capacity and was probably used for the transportation of cargo (fig. 2, no. 44, fig. 4; Kröger 2014, p. 102). Furthermore, along the Main several logboats with special functions have been documented. A 7th century find near Hassfurt can be interpreted as a floater for a ferry vessel due to its specific construction criteria (fig. 4; fig. 2, no. 47). Thirteen similar logboat floater have been dated to the 12th and 13th centuries, their characteristic are their small average dimension of 3 m length and 40 cm width as well as features like horizontal and vertical holes to connect several logboats to one raft and to fasten a solid wooden platform (fig. 12; Kröger in preparation; Kröger 2014, p. 102 and p. 107).

The toll regulation of Friedrich I. in 1157 AD (see above) does not only document the royal interest in free navigation, but also the importance of towing paths along the river Main. Those are described explicitly as *ripa fluminis quae via regia esse dinoscitur*, i.e. river shores, which are king´s roads. Nevertheless it is not clear, if this means that construction and maintenance of these towing paths have been royal duties (Ellmers 2007, pp. 165, 175-176). In 1165, Friedrich I. underlines that also the rivers themselves have been king's routes and at least nominal they remained so until modern constitutions (Schneider 2007, p. 191). Major interference in the waterway or at the banks such as the construction of a bridge to cross the river Main in Schweinfurt needed royal permission (Müller 2004, p. 18). Nevertheless, in the later Middle Ages the kings lost their influence on smaller rivers and upstream sections step by step, as it is documented for Heilbronn where the town is allowed to block the river Neckar in 1333 (Zimmermann 1954, pp. 9-11). If the reduced royal influence on smaller rivers is a consequence of problems of navigability caused by fluvial processes such as floodplain sedimentation or changing interests of the riverine stakeholders is unanswered yet.

5. Harbours and artificial waterways as nodes for navigation, 6th-13th century AD

To rest at least for a short time and to move people and cargo between water and land, ships are in the need of harbours. Every starting point and destination of a ship could be called a harbour. Usually, cargo and passengers could come in and get out of a ship at a harbour, vessels find protection, they can be pulled on the riverbank or be launched the other way. To fulfill these functions, a harbour may have specific buildings, but they are not mandatory (Ellmers 1984, pp. 123-174; Kalmring 2007, pp. 183-204; Wawrzinek 2014; Wunschel *et al.* 2015, p. 203). Following this definition, a huge number of harbours of the 6th-13th centuries could be identified in the study area based on written sources and the archaeological record (fig. 1, 5). Most of these harbours have been used for navigation upstream and downstream, but there are also ferry harbours to cross the river from one bank to the other, which will be discussed in greater detail below. Basically, a ferry harbour or – to be more precise – a pair of ferry harbours at both banks of a river, could also serve as a landing for ships going upstream and downstream; often a clear functional separation is impossible. Therefore, we integrated a certain number of ferry harbours in the general map of harbours (fig. 1, 5).

What happened with the roman harbours after Antiquity? Often it is unclear, some have been abandoned, but in urban centers such as Mainz and also at some minor sites harbours have been continuously used or reused. In the Rhine area, Trebur-Astheim and Zullestein provided evidence for a post-classical harbour function. In 846, a text describes that Zullestein *cum portu* has been transferred to the nearby monastery of Lorsch as an important gateway to the river Rhine (Elmshäuser 2002, pp. 39-40; Molkenthin 2006, p. 140; Heising 2012, pp. 162-163). During the 9th century, written sources enlighten a huge network of navigation which has been part of the monastic economy of Lorsch. Not only harbours, but also monastic ships, duties for navigation and exemptions from water tolls have been integral parts of this system (Elmshäuser 2002, pp. 39-43).

As there are no archaeological sources for most of the harbours and other places connected to navigation mentioned in the written sources, their precise localization is often problematic. Furthermore, the very common term *portus* is ambiguous (Niermeyer, Kieft 2002, p. 3743). To make the problem even bigger, many of the locations with mentioned duties for transports *cum navi* are not identical with the starting points of these transports and therefore the harbours (Elmshäuser 2002; Haase *et al.* 2015, pp. 159-166). Sometimes the harbour destination is more

Number on map	Name	River	Written sources for the harbour	archaeol. sources for the harbour	Dating (d: dendrodated)	Reference
13	near Teugn	Danube			mentioned 9th cent.	Winckler 2012
14	Regensburg	Danube	yes	yes	continuous use since Antiquity mentioned since 8th cent.	Codreanu-Windauer, Dallmeier 2015 Dallmeier, Kirpal 2011 Dopsch 2012 Hardt 2007 Molkenthin 2006
15	Graben	Altmühl	yes		mentioned 793	Werther *et al.* 2015 Hack 2014 Molkenthin 2006
16	Graben	Rezat	yes		mentioned 793	Werther *et al.* 2015 Hack 2014 Molkenthin 2006
17	Großhöbing	Schwarzach	no	yes	768d-855d	Liebert 2015
18	Amberg	Vils	yes		first mentioned 11th cent.	Molkenthin 2006
19	Forchheim	Regnitz		yes	first arch. proof 8./9. cent.	Ernst 2014
20	Bamberg	Regnitz	yes		first mentioned 11th cent.	Molkenthin 2006
21	Kitzingen	Main	yes		first mentioned 11th cent.	Hägermann 1995
23	Heidingsfeld	Main	yes		first mentioned 10th/11th cent.	Hägermann 1995
24	Würzburg	Main	yes	assumed	mentioned since 8th cent.	Molkenthin 2006
25	Karlburg	Main	no	yes	first arch. indications 7th cent.	Wunschel *et al.* 2015 Ettel 2011
26	Salz	Main	yes	assumed	mentioned 8th/9th cent.	Hack 2014 Molkenthin 2006
27	Seligenstadt	Main	yes		first mentioned 9th cent.	Patzold 2013 Molkenthin 2006
28	Frankfurt	Main	yes	yes	first mentioned 793	Hack 2014 Hampel 2013 Molkenthin 2006 Elmshäuser 2002
29	Biberich near Mainz	Rhein	yes		first mentioned 9th cent.	Molkenthin 2006
29	Ochsenfurt	Main	yes		first mentioned 11th/12th cent.	http://www.wubonline.de/ Band VI., Nr. N9, Seite 436-438 (27.01.2017)

Number on map	Name	River	Written sources for the harbour	archaeol. sources for the harbour	Dating (d: dendrodated)	Reference
30	Mainz	Rhine/ Main	yes	yes	continuous use since Antiquity	Molkenthin 2006 Elmshäuser 2002 Ellmers 1969
31	Camben	Rhine	yes		first mentioned 9th cent.	Molkenthin 2006 Elmshäuser 2002 Büttner 1967
32	Dienheim	Rhine	yes		first mentioned 8th cent.	Elmshäuser 2002 Büttner 1967
33	Gernsheim	Rhine	yes		9th/10th cent.	Elmshäuser 2002 Büttner 1967
34	Zullestein	Rhine	yes	yes	probably continuous use since Antiquity first mentioned and arch. proof 8th/9th cent.	Siemers 2011 Elmshäuser 2002 Büttner 1967
35	Lorsch	Weschnitz		yes	721/722d	Platz 2009
36	Weinheim	Weschnitz	yes		first mentioned 9th cent.	Molkenthin 2006 Elmshäuser 2002
37	Fossa Carolina (canal)	Altmühl/ Rezat	yes	yes	mentioned 793, 793d	Werther *et al.* 2015 Hack 2014
38	Schmidmühlen	Vils/ Lauterach	yes		first mentioned 11th cent.	Hensch 2013
39	Schwandorf	Naab	yes		first mentioned 11th/12th cent.	Wolfsteiner 2006
67	Gustavsburg	Main	yes		first mentioned 13th cent.	Flug 2006
68	Flörsheim	Main	yes		first mentioned 13th cent.	Hoßbach, Großmann 2003
69	Obernburg	Main	yes		first mentioned 13th cent.	Fischer-Pache 1993
70	Wörth	Main	yes		first mentioned 13th cent.	Trost 1989
71	Lengfurt	Main	yes		first mentioned 11th/12th cent.	Kuhn 2008
72	Steinbach	Main	yes		first mentioned 13th cent.	Höfling 1838
73	Haßfurt	Main	yes		first mentioned 13th cent.	Jäger 2010
74	Kemmern	Main	yes		first mentioned 13th cent.	Schrott 1986
75	Biegen/ Baunach	Main	yes		first mentioned 13th cent.	Jakob 1960

Fig. 5. Compilation of medieval harbours (6th-13th century AD) at selected rivers between Mainz and Regensburg (data collection: L. Kröger, A. Wunschel, L. Werther).

Fig. 6. Embankments at the Danube waterfront of Regensburg "Donaumarkt" made of re-used Roman material, probably Carolingian (S. Codreanu-Windauer, BLfD 2014).

precise: to give an example, the inhabitants of several farmsteads of the monastery of Prüm have to transport cargo *cum navi* to the harbour of St. Goar in the Carolingian period (Elmshäuser 2002, p. 51). The highest geographic precision is the mentioning of a specific building complex where ships had to be unloaded, such as the transports starting around Worms *cum navi ad regis edificium* in Frankfurt – which is the royal palace used by Charlemagne and many others from 793/94 onwards (Elmshäuser 2002, p. 37; Ehlers 2013, p. 12). Until now, there is no archaeological proof for that early harbour in Frankfurt, but it is obvious that it was located further inland than the modern riverbank (Ehlers 2013; Hampel 2013).

Even if there have been excavations, it is often difficult to provide clear evidence for inland harbours, as simple landing places consisting of a flat, more or less unmodified section of the bank seem to be the most common type. At first sight, they seem primitive, but they have been perfectly suitable for fluctuating water levels, shifting banks and meandering

rivers as the effort for construction, maintenance and relocation has been minimal. Vessels could use these harbours under almost all conditions and it was easy to haul them on the bank for protection or repair. In the last years, two of these landing places – perhaps without any specific construction – have been investigated in Karlburg at the banks of the Main and in the early medieval royal palace of Salz at a tributary (Wunschel *et al.* 2015).

Nevertheless, at least at the main rivers – as in Antiquity – there have also been more complex harbour constructions, perhaps even made of stone. In Zullestein (Jorns 1979; Siemers 2011) and also in Regensburg (Codreanu-Windauer, Dallmeier 2015, p. 22) stone walls (fig. 6) presumably serving as a quay in the Carolingian period have been excavated, but their interpretation is not unambiguous. Whereas the early medieval harbour has not been found yet by archaeologists (see above), the 13th / 14th century harbour of Frankfurt with a high-quality masoned quay wall has been documented some years ago (fig. 7; Ehlers 2013; Hampel 2013). In 1149, written sources give an idea of the capacity of the older 12th century harbour, as archbishop Albero arrives at an assembly in Frankfurt with an asserted number of 40 boats, among them special kitchen vessels (Ehlers 2013, p. 14) – and he was only one of many guests.

Fig. 7. Excavation of the 13th-14th century quay wall at the Main waterfront of Frankfurt "Saalhof", view from the river (Denkmalamt Frankfurt am Main 2012).

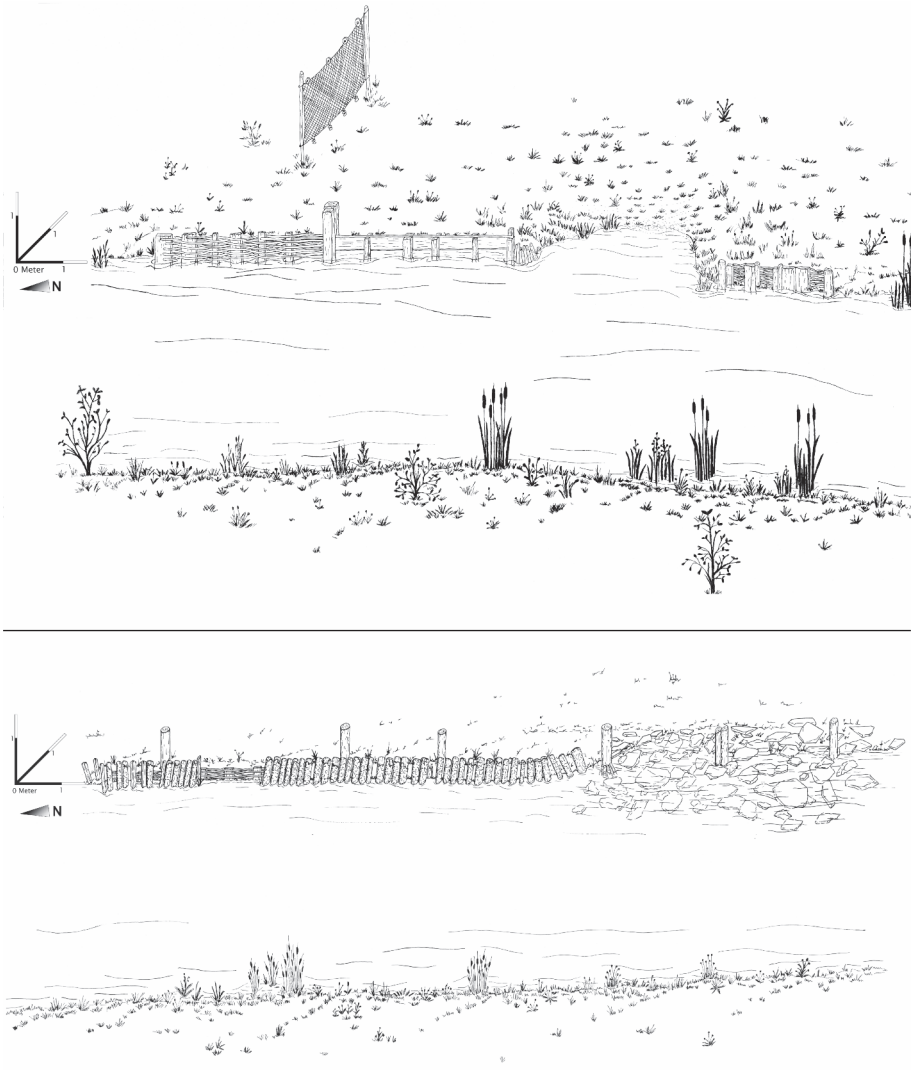

Fig. 8. Reconstruction of the Carolingian landing place of Großhöbing at the river Schwarzach. Top: period 2, dated to 819 AD. Bottom: period 4, dated to 854/55 AD (after Liebert 2015).

Like in Antiquity, river banks with an unfavorable ground have been paved extensively with stone and wattle layers. The best example is a mid-9th century landing place with a stone pavement excavated in Großhöbing at the river Schwarzach (Liebert 2015, pp. 51-87). This pavement (fig. 8) has been combined with wooden bank reinforcements

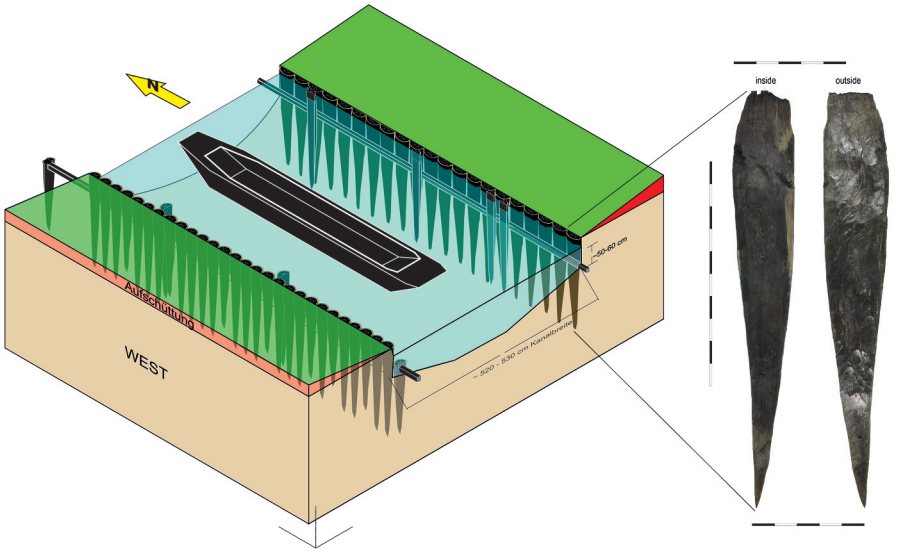

Fig. 9. Reconstruction of the canal construction of the *Fossa Carolina* dated to 793 AD based on the excavation 2013 with an original oak pile of the bank reinforcement (drawing F. Herzig, L. Werther).

which served as a simple quay to moor smaller ships. For bigger vessels, this harbour at the limits of navigability of the river Schwarzach has not been accessible, but the proximity to the European watershed made it a perfect point of transshipment to reach the tributaries of the river Rhine via a short portage (Liebert 2015, pp. 67-87).

It is obvious that bridging this watershed was of a particular importance already in the Early Middle Ages. This is clearly documented by the attempt of Charlemagne to build an artificial canal in 793, the famous *Fossa Carolina* (fig. 9) which should create a continuous waterway between Rhine and Danube (Ettel *et al.* 2014; Zielhofer *et al.* 2014; Werther *et al.* 2015). Intensive research in the last years indicates, that at least the northern part of this ambitious project was almost finished and ready to use. The excavated canal fairway with wooden bank stabilizations (fig. 9) is 5,2-5,3 m wide, the minimal water depth was about 50 cm (Werther *et al.* 2015, pp. 156-173). The dimension of the fairway is very similar to the 9th century artificially modified Schwarzach channel at the harbour of Großhöbing (fig. 8; Liebert 2015, pp. 67-87). Therefore, these fairways close to the watershed document the minimal requirements for Carolingian vessels at the limits of navigation.

6. Bridges, fords and ferries: crossing the rivers Main and Regnitz

Watersheds between rivers have not been the only obstacles for medieval traffic and communication. The rivers themselves have been an obstacle, because crossing the river from one bank to the other, which has been an essential part of everyday mobility not only of the elites but also the general public (Elmshäuser 2002; Hägermann 2002), caused many problems. If a longer river section was only crossable at a certain place, traffic concentrated there. These bottlenecks often gained importance, resulting in an increase of written sources – and they allow for a detailed analysis concerning the connection between terrestrial routes and waterways. Based on a PhD thesis on river crossings at Main and Neckar this topic will be discussed in the last part of this article (see Kröger in preparation with many more details).

The three main types of river crossings are bridges, fords and ferries, but based on written sources a clear terminological distinction is not always possible – and also the distinction from harbours for navigation upstream and downstream is not always clear (see above). Due to the ambiguous medieval terminology a separation between bridges and ferries is especially problematic. Only in a few cases, it is clear that a crossing was really a bridge und not a ferry service or "Schiffsbrücke" [i.e. boat bridge]. The terminus *pons*/*ponte* is still in use for ferries nowadays in some regions (Ellmers 1973, p. 53; see also Niermeyer, Kieft 2002, p. 3729). The mentioning of a *navium dicti varbrucken* in 1359 in Ochsenfurt shows that variations of the term *brucken/bridge* have also been used to describe a vessel crossing the river (Wenisch 1972, p. 42).

Furthermore, a separation between a ferry and a harbour for navigation along the river is in fact not possible, because every ferry station consists of two small harbours or landing places (fig. 12). This ambiguous character is also documented in the written sources, especially for early and often very short mentions. To give an example, the bishop of Würzburg is provided with a fiefdom for a *naulum* by Konrad II. in 1030, which is translated as a ferry wage (Seberich 1958, pp. 16 and 157-158), but it may also be a payment for other duties related to navigation (Adam 1996, p. 53). In Kitzingen, the monastery gets fees for a *portus* in 1070, which can be interpreted either as a ferry payment or a landing place (Arnold 1996, pp. 25 and 46-47).

In some cases, especially if the sources are more detailed, bridges can clearly be identified. In Antiquity, there have been several bridges in the study area, but their usability in the Middle Ages is usually unclear (Frohnhäuser 1870, p. 9; Steidl *et al.* 2008). In Mainz, Charlemagne renovated the roman bridge crossing the Rhine, but it was destroyed by

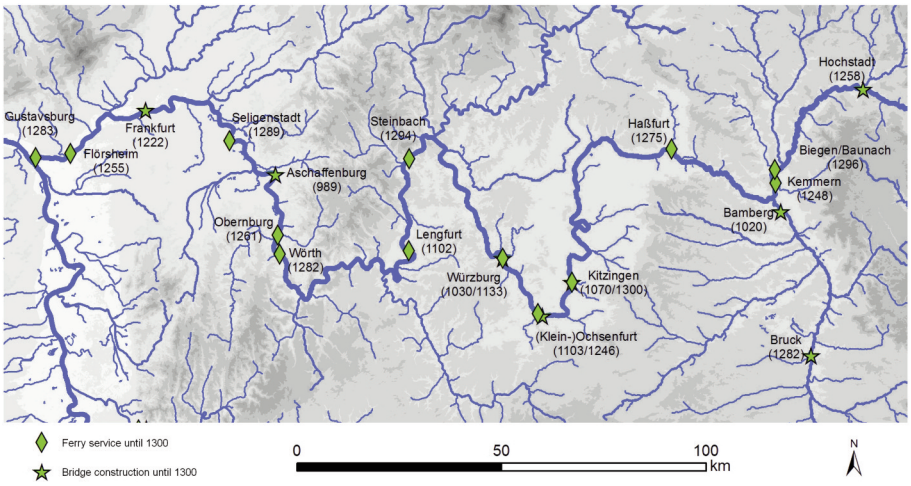

Fig. 10. General map of medieval ferry stations and bridges at the rivers Main and Regnitz from the beginning to the 13th century AD (status 2016; map data SRTM-GDEM © NASA 2009, CCM River and Catchment Database © European Commission 2007).

a fire soon and not rebuilt for centuries (*Regesta Imperii* RI I – Karolinger n. 477a). There is no clear archaeological evidence for early medieval bridges, but at least in Seligenstadt some undated remains may be from this period (Fabricius 1914, pp. 3-4; Gündel 1933, pp. 137-138).

The oldest bridges at the rivers Main and Regnitz are mentioned in the 10th century AD, until the 13th century they are documented in Frankfurt, Aschaffenburg, Würzburg, Ochsenfurt, Kitzingen, Hochstadt, Bamberg and Bruck (figs. 10, 11). In 989 the earliest source describes a *Pontem construxit apud Aschaffenburg* (Fischer 1989, pp. 40-41). In 1020 the Bamberg bridge is first mentioned, the earliest archaeological remains date to the 12th century (Menke 2009, pp. 111-112). In Würzburg, a bridge constructed by the cathedrals master builder is first mentioned in 1133 (Seberich 1958, pp. 16-21, 158-159). As discussed for Schweinfurt above, the construction of a bridge had to be approved by the king. Usually, the king did not give the right for a specific construction, but the right to cross the river at a certain place. Once such a right has been granted, no new permissions have been necessary to rebuild and repair a bridge, if it was destroyed e.g. by floods and ice drift. To support the maintenance of bridges, special privileges for the supply of building material such as wood have been granted by the king, for example after the first destruction of the bridge in Frankfurt in 1235 (Gorr 1982, p. 77; Wissenbach 2010, pp. 11, 16).

Name	River	River kilometer	Technique	First mention	References
Gustavsburg	Main	1,3	Ferry	1283	Flug 2006
Flörsheim	Main	11,8	Ferry	1250/60	Hoßbach, Großmann 2003
Frankfurt	Main	35,6	Bridge	1222	Wissenbach 2010 Gorr 1982
Seligenstadt	Main	69,5	Ferry	1289	Koch 1940
Aschaffenburg	Main	87,5	Bridge	989	Fischer 1989
Obernburg	Main	104,5	Ferry	1261	Fischer-Pache 1993
Wörth	Main	110	Ferry	1282	Trost 1989
Lengfurt	Main	174	Ferry	1102	Kuhn 2008
Steinbach	Main	200	Ferry	1294	Höfling 1838
Würzburg	Main	252,5	Ferry	1030	Seberich 1958
Würzburg	Main	252,5	Bridge	1133	Seberich 1958
(Klein-)Ochsenfurt	Main	271	Ferry	1103	Kampfmann 1990
(Klein-)Ochsenfurt	Main	271	Bridge	1246/47	Wenisch 1972 Keyser, Stoob 1971
Kitzingen	Main	286,8	Ferry	ca. 1070	Arnold 1996
Kitzingen	Main	286,8	Bridge	1300	Badel, Christof 2000
Haßfurt	Main	361,7	Ferry	1275	Jäger 2010
Kemmern	Main	400	Ferry	1248	Schrott 1986
Biegen/Baunach	Main	403	Ferry	1296	Jakob 1960
Hochstadt	Main	451	Bridge	1258	Müller 1990
Bamberg	Regnitz	5	Bridge	1020	Menke 2009
Bruck	Regnitz	51,4	Bridge	1282	Birkholz 2008

Fig. 11. Compilation of ferries and bridges at Main and Regnitz until 1300 AD (data collection: L. Kröger).

Ferries are an important alternative to bridges and they have been used frequently in the study area, as already discussed concerning logboats as parts of ferries proofed from the 7th century AD onwards at the river Main (fig. 1, no. 47). Nevertheless, written sources about the users of ferries, transported goods and technical facilities are very scarce before the 13th century. In 1102, the monastery Triefenstein in Lengfurt is provided with a ferry by the bishop of Würzburg (Kuhn 2008, p. 171). It is very typical that the early sources have been written down when ownership changed (e.g. Gustavsburg, 1283, Flug 2006, p. 203; Seligenstadt, 1289, Koch 1940, p. 136). In contrast to the Early Middle Ages, later on ferries did no longer belong to the kings properties or have been directly subordinated to him. Instead, local lords and institu-

tions – like the bishop of Würzburg – controlled them independently (see Kröger in preparation). Once the ferry fiefdom was awarded, it could have been given from one owner to another, which happened frequently. To give an example, in 1103 the fiefdom of the ferry in Kleinochsenfurt at the river Main is transferred by a local lord to the monastery of Hirsau, which he later joins. In 1150 the fiefdom was given to the priory Schönrain near Gemünd and in 1251 to the monastery Neustadt near Lohr (Kampfmann 1990, pp. 23-24). In rare occasions, specialists operating these ferries are also mentioned in the sources, e.g. *Conradus dictus Verhe* [i.e. ferryman] *de Werde* in 1282 (Trost 1989, pp. 301-302). With the increase of written sources from the end of the middle ages, more information on the complex legal framework, taxing and daily routing of ferries is available, but projection to earlier periods is often problematic (see Kröger in preparation).

In addition to bridges and ferries, fords are an essential means of crossing a river (see the comprehensive discussion in Kröger in preparation, we focus on selected issues here). Often fords are considered as the oldest way to cross a river and therefore nuclei for later settlements, but the meaning of the medieval term "ford" is not always clear and alternative interpretations have to be discussed. Furthermore, fords have also been a serious obstacle for traffic, especially for navigation. It has been discussed, that medieval flat bottomed ships have only a small draught, but still the river should have a minimum depth which is not always given at fords (Kröger 2014). Whereas a higher water depth was therefore favourable for navigation, pedestrians had the opposite interest, as crossing deeper rivers is not only uncomfortable, but also dangerous. In 1830, Prussian officers have still been warned to walk their troupes through rivers deeper than 78 cm, even with a stable ground and slow current (Hoyer 1830a, pp. 76-77; Hoyer 1830b, pp. 58-76).

Geomorphological changes and seasonal hydrological variations caused further problems for the use of fords – and for their localisation. Before floodplain sedimentation increased significantly at the end of the Early Middle Ages, the active channel of the river Main has been rather deeper than later on (Fuchs *et al.* 2011; Schirmer 2007). Furthermore, even in the post-medieval period no ford between Mainz and Bamberg has been traversable all-the-year. In order to localise older fords at shallow sections of the river, usually place names with the suffix "Furt" [i.e. ford] are the initial point and the main argument. From the 8th century onwards, *furtes* are mentioned in written sources of the study area, like in a border description of 779 AD for Heidingsfeld at the river Main (Borchardt 2005, p. 65), but usually the sources are significantly younger. Further-

Fig. 12. Reconstruction of a characteristic ferry station with vessels at the river Main around 1300 AD (© L. Kröger, drawing: F. Frese).

more, the term "Furt" is not necessarily connected to fluvial locations and river crossings. It is a deduction of the German term "Fahren" [i.e. drive], which could also include "Fähren" [i.e. ferries] and allows no statement of the nature of the crossing (Tiefenbach 1989, pp. 268-269). To give an example, the term has also been used for pass roads crossing a height, like "*Furth im Wald"* (i.e. ford in the forest) in Bavaria. Also the Latin term *vadum* is translated to German exclusively as a shallow section of the river or ford (Stowasser *et al.* 1994, p. 537), which is not appropriate. Therefore, the term "Furt/*vadum*" should be translated more generally as passage or crossing, and not as ford – like it is common in French or in English with the translation "*passage de rivière*" or "*river crossing*", which does e.g. also include a transport by boat (Niermeyer, Kieft 2002, p. 1381). A 14th century document concerning the river Main offers a vivid example for this ambiguity: In 1344, a *vadum* […] *quod vulgariter dicitur eyn far*, i.e. a *vadum* [usually translated as ford] which is generally called

a *Far*/ferry, is described for Obernburg (unpublished charter from 9th July 1344 of the monastery St. Peter and Alexander in Aschaffenburg, today in the town archive Aschaffenburg, U 1658).

As ferries are proofed by archaeological remains like in Mariaburghausen near Eltmann (fig. 4; fig. 1, no. 47) for the 7th century onwards, traditional interpretations of river crossings along the Main exclusively as fords, like for the important medieval passage in Frankfurt (Holtzmann 2007, p. 206), have to be challenged. The boundaries between the different means of river crossings, vessels, harbours and navigation are fluid, as they are all part of one complex system of communication in the shifting fluvial landscape.

7. Outlook

In our article, we tried to integrate a very heterogeneous set of issues and sources on harbours, vessels, river crossings, people and cargo into one combined history of shifting fluvial landscapes and societies. Initially, the editors of this volume asked us for two individual articles, as usually these issues and sources are separated. We hope that our decision to dare an integrative approach may be a stimulus for future research in our study area. Many topics are not analysed in detail and in a representative way for the whole study area yet, and even more integral parts of the fluvial landscape have not been treated at all, such as mills, urban hydraulic engineering, fisheries, dams and the general fluvial dynamics with the continuous struggle between men and nature as well as different interests. Nevertheless, we hope that our study could help to enlighten the potential of such an integrated analysis for a deeper understanding of rivers in the post-classical period.

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