Journal of Environmental Management 202 (2017) 403–411

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Fish and fisheries in the Lower Rhine 1550–1950: A historical-ecological perspective

H.J. Rob Lenders

Radboud University Nijmegen, Institute for Water and Wetland Research (IWWR), Department of Environmental Science, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

ARTICLE INFO

Article history:
Received 13 June 2016
Received in revised form
1 September 2016
Accepted 3 September 2016
Available online 9 September 2016

Keywords:
Atlantic salmon
European/Atlantic sturgeon
Allis shad
Twaite shad
Long-term stock development

ABSTRACT

Regulation and intensive use of most of the world's large rivers, has led to dramatic decline and even to extinction of riverine fish populations like salmon and sturgeon in the river Rhine. In general this decline is considered an unwelcome side-effect of the Industrial Revolution and large-scale river regulation (c. 1800), but the deterioration of stocks of some species may have started well before the 19th century. For the river Rhine, data on fish landings as proxies of abundance in the period 1550–1950 can be derived from historical market prices, fisheries taxation and fishery and fish auctions statistics, especially for commercially interesting species like Atlantic salmon, sturgeon, Allis shad and Twaite shad. Most data from which abundance of these species can be derived, however, appear to be missing in historical sources until decline of the investigated species sets in and the species become economically scarce goods. Atlantic salmon in the Rhine catchment appears to be already in decline during Early Modern Times (post 1500 AD) after which time river regulation, pollution and intensified fisheries finished off the remaining stocks in the 20th century. Salmon decline caused a cascade in the River Rhine ecosystem as fisheries shifted to, especially, Allis shad and Twaite shad, followed by (near-)extinction of these species. Dropping yields of salmon fishery did not lead to increased sturgeon fishery, although numbers of sturgeon also dwindled to extinction in the river Rhine. The onset of sturgeon decline appears to coincide with the period of the first large regulation works. It is shown that historical-ecological data on fish abundance can quantitatively underpin detrimental long-term processes in river ecosystems.

1. Introduction

There is growing scientific and management interest in long-term ecological developments, both for establishing references or the historical range of variability (HRV) for ecological rehabilitation purposes and for understanding ecological processes on temporal scales of centuries to millennia, including the human impact on them (see, e.g., Jackson et al., 2001). Understanding historical-ecological processes and causes of decline helps in setting targets for restoration but also to identify the exact points of engagement; which factors are ultimately responsible for decline and how can these factors be conversed for the better? A great deal historical-ecological studies concern the decline of marine and fresh water fish stocks. Besides the fact that fish are among the most threatened species globally, this historic interest is grounded in a wealth of potentially interesting historical data on fish. In many archaeological excavations and historical written sources much attention goes out to fish since they were (and are) an important resource of human subsistence. Nevertheless, long-term developments in fish stocks are still poorly understood or cover relatively short periods leading to the occurrence of what Pauly (1995) calls the *shifting baseline syndrome* determining what we consider to have been healthy fish stocks in the past of what were already often decimated populations (see also Humphries and Winnemiller, 2009; Papworth et al., 2009). Usually the consistency of available data is considered to be a limiting factor in reconstructing reliable long-term developments, but also prepossessions regarding the alleged reasons for decline often prevent examination beyond this point. Reconstructing fish stocks, for example, does often not go further back in time than the Industrial Revolution or the start of river regulation in the early 1800s. In his ground-breaking 1996 paper “a brief history of aquatic resource use in medieval Europe” Hoffmann already ascertained that “the much-studied Rhine and its major tributaries (…) are said to have suffered little from human activity before canalizing and embanking in the

E-mail address: R.Lenders@science.ru.nl.

http://dx.doi.org/10.1016/j.jenvman.2016.09.011
0301-4797/

early nineteenth century began a total degradation. But most studies of major European rivers start from a present and retrospective standpoint with little deeper historical knowledge or awareness". Moreover, many studies examine developments in stocks of specific species without addressing ecological and/or exploitation relationships with other species. An important exception is the publication by Pauly et al. (1998) who demonstrated a transition in marine fish landings from long-lived, high trophic level species to short-lived, low trophic level species.

As in most other heavily regulated and intensively used rivers, riverine fish in the River Rhine, especially anadromous species, have faced serious declines (e.g., Paalvast and Van der Velde, 2014; Wolter, 2015; Wolter et al., 2005). In the 20th century, Atlantic salmon (*Salmo salar*) and European/Atlantic sturgeon (*Acipenser sturio*/*oxyrinchus*) became effectively extinct. Although the Industrial Revolution (c. 1800) has most certainly speeded up the decline of riverine fish stocks in the river Rhine, there is also growing awareness that the decline of some species may have started much earlier in history (De Groot, 2002; Hoffmann, 1996; Lenders et al., 2016). The question subsequently arises whether the early downfall of certain species has had a cascading effect in the river ecosystem, either because of ecosystem-internal causes, for instance disrupted food webs, or as a result of changing human ecosystem exploitation, for instance shifts in the species fished for. In this article I explore the availability of quantitative data from different origin to reconstruct historical developments in stocks of Atlantic salmon, European/Atlantic sturgeon, Allis shad (*Alosa alosa*) and Twaite shad (*Alosa fallax*). The species under consideration were selected since they are relatively frequently mentioned in written historical sources that hold direct or indirect quantitative information on fish (numbers, weight, prices, taxes). Subsequently, it was examined whether there is a plausible mutual relationship between stock development of separate species. The geographical focus of this study is on the lower course of the River Rhine in Germany and The Netherlands; the temporal focus on post-medieval Modern Times.

2. Material and methods

Since fish is and has always been an important resource for humans in Europe, there is a wealth of historical data available including zooarchaeological records dating back to the Mesolithic and written accounts from Roman Times onwards. Quantitative data for NW-Europe from written sources only become available from high medieval and later toll registers, manor and monastery accounts, market data, taxations and fishery and fish auction statistics. Consistent time series of quantitative data, however, are scarce and require careful consideration. Compiling series from scattered data is even more difficult. An overview of potentials and limitations of using and interpreting historical fish data is given by Haidvogl et al. (2014, 2015). For the present study existing publications comprising time series of market prices, taxation, fish auction and fishery statistics were used to compile stock developments of Atlantic salmon (*Salmo salar*), European/Atlantic sturgeon (*Acipenser sturio*/*oxyrinchus*), Allis shad (*Alosa alosa*) and Twaite shad (*Alosa fallax*) in (parts of) the Lower Rhine in Germany and The Netherlands from approximately 1550 to 1950. Since in historical sources, no distinction can be made between European sturgeon (*Acipenser sturio*) and Atlantic sturgeon (*Acipenser oxyrinchus*), species only recently acknowledged as *both* living in Europe's Atlantic coasts and rivers in the historical past (see, e.g., Ludwig et al., 2002; Thieren et al., 2016), they are here therefore treated as a single species. An overview of time series used per species, including time coverage, geographical location, data types and references is given in Table 1.

The species selected represent anadromous species with a highly divergent usage of the longitudinal dimension of the river. Atlantic salmon (*Salmo salar*) makes use of the full longitudinal gradient, maturing in the marine environment and reproducing in the upper reaches of the river system. For most specimens reproduction is restricted to one single event. Both long-lived sturgeon species also spend most of their lifetime in the sea, and spawn and grow up in rivers. In contrast to salmon, however, sturgeons use deep gravel beds in the main channel of the river as spawning grounds. Allis shad (*Alosa alosa*) and Twaite shad (*Alosa fallax*) both also live for a large part of their life in marine environments; Allis shad, however, reproduces in the upper reaches of the main river branches while Twaite shad mostly spawns in the lower reaches of the river up to where tidal movements are still just detectable. Sturgeon, Allis shad and Twaite shad have in general multiple

Table 1
Sources of time series per species with indication of time period, geographical location and data type.

Species	Time period	Location	Data type	Reference
Acipenser sp.	1566–1916	Germany, Rhine	Length per individual	Kinzelbach (1987)
Acipenser sp.	1573–1943	Germany, Rhine	Weight per individual	Kinzelbach (1987)
Acipenser sp.	1742–1775	Netherlands, Rhine/Meuse, Geertruidenberg	Numbers at fish auctions	Martens (1992)
Acipenser sp.	1885–1909	Netherlands, Rhine/Meuse, Kralingse Veer	Numbers at fish auctions	Hoek (1910)
Acipenser sp.	1893–1952	Netherlands, Lower Rhine/Meuse, Hardinxveld	Numbers at fish auctions	De Jong et al. (1988)
Acipenser sp.	1895–1920	Netherlands, Rhine	Numbers at fish auctions	De Jong et al. (1988)
Acipenser sp.	1895–1920	Netherlands, Lower Rhine/Meuse, Hardinxveld	Price per specimen vs numbers at fish auction	De Jong et al. (1988)
Acipenser sp.	1898–1923	Germany, Rhine, Düsseldorf	Numbers caught	Böcking (1988)
Acipenser sp.	1898–1923	Germany, Rhine, Düsseldorf	Weight per individual	Böcking (1988)
Acipenser sp.	1900–1931	Netherlands, Rhine/Meuse	Numbers caught	Verheij (1949)
Alosa alosa	1875–1910	Netherlands, Rhine/Meuse	Number at fish auctions (5-year averages)	De Jong et al. (1988)
Alosa alosa	1877–1932	Netherlands, Lower Rhine/Meuse	Number at fish auctions (5-year averages)	De Jong et al. (1988)
Alosa alosa	1893–1919	Netherlands, Lower Rhine/Meuse	Numbers at fish auctions	De Jong et al. (1988)
Alosa fallax	1893–1959	Netherlands, Lower Rhine/Meuse	Numbers at fish auctions	De Jong et al. (1988)
Salmo salar	1550–1600	Germany, Rhine, Cologne	Market prices	Kuske (1905)
Salmo salar	1650–1800	Netherlands	Tax revenues	Van der Woude (1988)
Salmo salar	1798–1810	Netherlands, Rhine/Meuse, Geertruidenberg	Price per specimen vs numbers at fish auction	SCZV (1916)
Salmo salar	1798–1827	Netherlands, Rhine/Meuse, Geertruidenberg	Numbers at fish auctions	Martens (1992)
Salmo salar	1820–1824	Netherlands, Rhine, Schoonhoven	Numbers at fish auctions	SCZV (1916)
Salmo salar	1863–1955	Netherlands, Rhine/Meuse	Numbers at fish auctions	De Jong et al. (1988)
Salmo salar	1870–1912	Netherlands, Rhine/Meuse, Kralingse Veer	Numbers at fish auctions	SCZV (1916)
Salmo salar	1885–1939	Netherlands, Rhine/Meuse	Numbers caught/at fish auctions	De Nie (1997)
Salmo salar	1890–1914	Netherlands, Rhine/Meuse	Numbers caught	SCZV (1916)
Salmo salar	1921–1955	Netherlands, Lower Rhine/Meuse, Hardinxveld	Numbers at fish auctions	De Jong et al. (1988)