Limnologica 59 (2016) 53–62

Contents lists available at ScienceDirect

Limnologica

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

Drift of fish larvae and juveniles in the Lower Rhine before and after the goby invasion

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ARTICLE INFO

Article history:
Received 19 December 2015
Received in revised form 28 April 2016
Accepted 4 May 2016
Available online 17 May 2016

Keywords:
Reproduction
Invasive
Spawning season
Drift strategy
Rutilus rutilus
Barbus barbus
Neogobius fluviatilis
Neogobius melanostomus
Ponticola kessleri

ABSTRACT

Drift is described as a dispersal mechanism inherent in many freshwater fish species. The main aim of this study was a comprehensive description of drift patterns of three invasive gobies living in sympatry, and to compare these results with similar sampling efforts before the occurrence of invasive gobies at the River Rhine. More than 26,500 larvae and juvenile fishes were caught with drift nets in 2000 and 2012–2014. Though some species were missing in 2012–2014 (e.g. bullhead *Cottus gobio* and gudgeon *Gobio gobio*), only low differences were found in the drift of autochthones before and after the goby invasion with respect to abundances or sizes. Roach (*Rutilus rutilus*) and bighead goby (*Ponticola kessleri*) increased in size over the season, indicating a somewhat different drift strategy than for barbel (*Barbus barbus*), monkey goby (*Neogobius fluviatilis*) and round goby (*N. melanostomus*) that drifted over several months, but remained at a similar size. The drift data give a first indication that the potential impact of gobies in the River Rhine should act on other stages than on the very first larvae within the life-cycle of important members of the local fish communities. The data also clearly reveal that bighead goby is actually at the bust phase within typical boom-and-bust cycles of invasive species, while round and monkey goby have not yet left the boom phase so far at the Lower Rhine.

1. Introduction

Drift is described as a dispersal mechanism inherent in many freshwater fish species (Lucas and Baras, 2002), which (1) may play an important role in the population and metapopulation dynamics of many species (Reichard and Jurajda, 2007), (2) may enhance species diversity and gene flow (Lechner et al., 2014), (3) is assumed to reduce competition and predation (Humphries, 2005), and (4) is often described as an essential period within the ontogenetic life-cycle (Pavlov, 1994). Though drift is described mainly as a passive transport mechanism in rivers with buoyant eggs and small larvae being carried downstream, its initiation within the lifecycle can be either active or passive (Lucas and Baras, 2002). The latter is certainly true for those fishes which have (at times) pelagic eggs, such as many characins (e.g. Araujo-Lima and Oliveira, 1998) or some freshwater Clupeidae (e.g. Bilkovic et al., 2002). Passive drift initiation may further be affected by species-specific behavior with respect to hatching. For instance, migratory coregonid larvae begin to swim immediately after hatching. As they are positively phototactic, they move towards the surface (Fabricius and Lindroth, 1954; Lindroth, 1957), where they immediately start to drift in running waters (e.g. North Sea houting, *Coregonus oxyrinchus*, Borcherding et al., 2014). However, there are also many species that exhibit behavioral patterns at certain life stages that are considered as "active elements" within the passive downstream migration (Pavlov, 1994).

Different drift strategies and their initiation have evolved as adaptations of the species-specific lifecycle within specific conditions of a particular environment (Pavlov, 1994), such as the European River Rhine that went from the 19th century onwards through long lasting periods of river degradation and its secondary changes in biotic communities. The fish community of the Lower Rhine had recovered from its historically worst periods at the end of the 1960s, when water quality began to improve in the 1980s (Borcherding and Staas, 2008). Since then, most fishes from historical periods were found to be back in the Lower

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http://dx.doi.org/10.1016/j.limno.2016.05.001

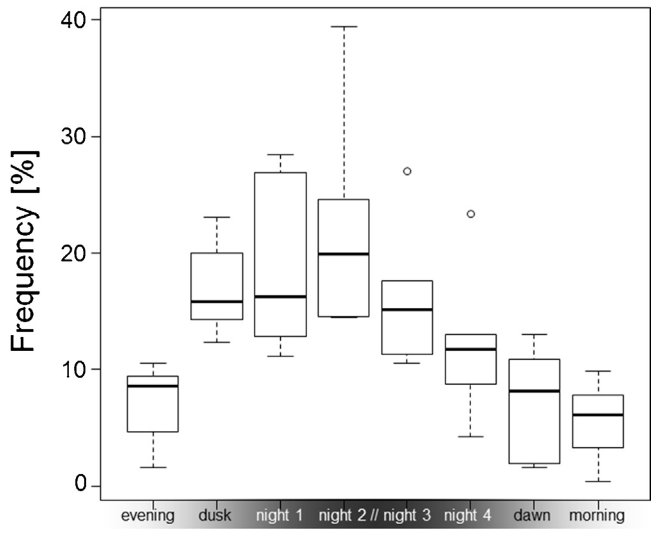

Fig. 1. Frequency of drifting fishes in relation to the time of day (estimates resulting from GLM) caught at 6 days between the end of May and the end of August 2013 at the Rhine station in Cologne (diel samples: sunset, 45′ after sunset, 90′ after sunset, 150′ after sunset, 150′ before sunrise, 90′ before sunrise, 45′ before sunrise, sunrise). Box Whisker: Median, Box = 25–75% Quartile, Whisker Min-Max (if Min or Max were more than 1.5 fold larger or smaller than the Inter quartile range, these values are expressed as outliers [circles]).

Rhine, though sometimes in low numbers (actual lists can be found here: http://www.rheinfischerei-nrw.de/fischerei-themen/fischfauna-des-rheins/). Even extinct migratory species like the North Sea houting were recently reintroduced and have established a self-reproducing population that has dispersed over the whole Rhine delta (Borcherding et al., 2010; Borcherding, 2011).

Morphological and hydrological alterations in the River Rhine were added by biotic changes of the ecosystem. After the opening of the Rhine–Main–Danube-Channel in 1992, the southern corridor served as an entrance door for the introduction of invasive species (Bij de Vaate et al., 2002). In 1986, 12% of the benthic invertebrates of the 850 km of navigable Rhine were non-native (Kureck, 1992), while in 2000, 80% of all species belonged to this group, and in terms of biomass the invasive species had even increased to more than 90% (A. Kureck, personal communication). The first gobiid species detected in the Lower Rhine was the tubenose goby (*Proterorhi-*

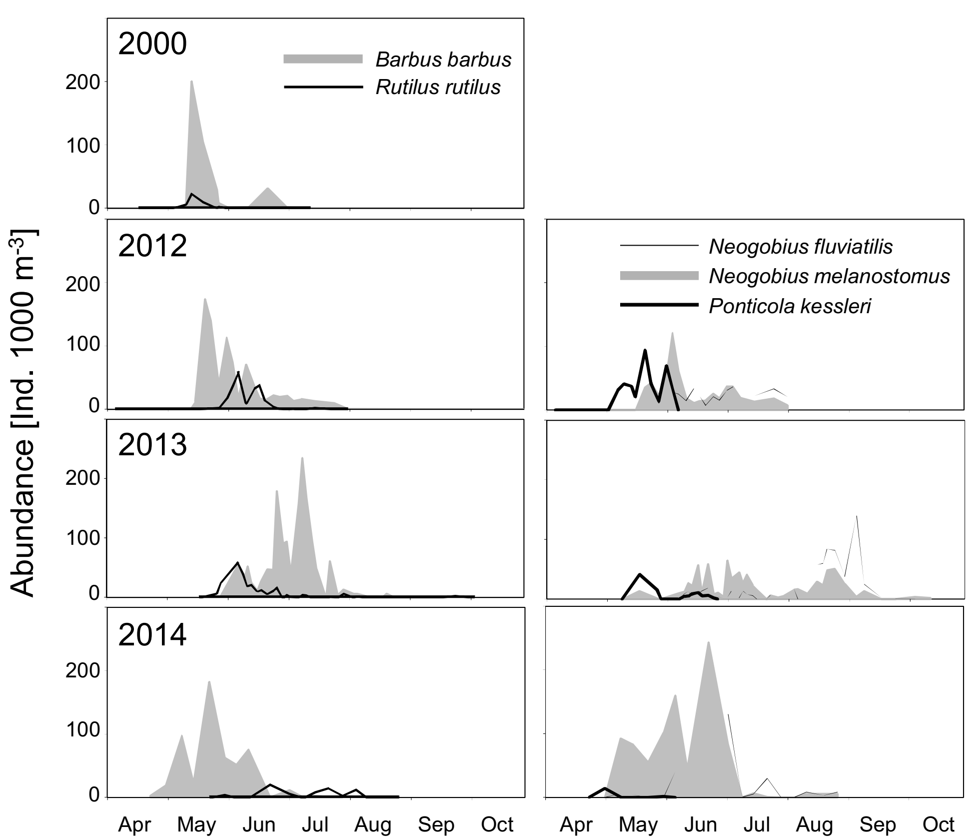

Fig. 2. Seasonal patterns in drift abundance of *Barbus barbus*, *Rutilus rutilus* (left panels), *Neogobius fluviatilis*, *N. melanostomus* and *Ponticola kessleri* (right panels) over the sampling season for different years at the Rhine station in Cologne.