DISTRIBUTION REVISED- FIFTEEN YEARS OF CHANGES IN THE INVASION OF A FRESHWATER FISH, *PSEUDORASBORA* *PARVA* (TEMMINCK AND SCHLEGEL, 1846) IN TURKEY

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ABSTRACT

The aim of the present paper is to revise the distribution range of the invasive freshwater fish species, topmouth gudgeon *Pseudorasbora parva* (Temminck and Schlegel, 1846) in Turkey, based on the literature review. After the first report of the species from the Meriç River in Thrace (European part of Turkey) in 1982, it has spread across the country mainly through human-mediated accidental introductions. The species has now been reported from 66 water bodies in total. Besides the introduction pathways, we also present chronological distribution pattern of the species. This information is useful especially for conservation endemic ichthyofauna due to the negative impact of *Pseudorasbora parva*, particularly through introducing an emerging infectious eukaryotic intracellular pathogen on the fungal-animal boundary, *Sphaerothecum destruens* Arkush et al., 2003.

ZUSAMMENFASSUNG: Eine überprüfte Verbreitung- fünfzehn Jahre von Veränderungen betreffend die Invasion des Süßwasserfischs *Pseudorasbora parva* (Temminck und Schlegel, 1846) in der Türkei.

Ziel der vorliegenden Arbeit ist es, auf Grund der Durchsicht neuerer Fachliteratur das Verbreitungsgebiet des Süßwasserfischs *Pseudorasbora parva* (Temminck und Schlegel, 1846) in der Türkei zu revidieren. Nach einer ersten Meldung der Art im Meriç-Fluss in Thrakien (europäischer Teil der Türkei) im Jahr 1982 hat sich die Art im Land vorwiegend über zufälliges Einschleppen durch den Menschen verbreitet und wurde gegenwärtig insgesamt aus 66 Gewässern gemeldet. Es werden auch die Einschleppungswege und die chronologischen Verbreitungsmodelle der Art dargestellt. Diese Information wird als nützlich erachtet, vor allem im Hinblick auf den Erhalt der endemischen Fischfauna, wegen des negativen Einflusses von *Pseudorasbora parva* durch das Einschleppen eines eukaryotischen, intrazellulären ansteckenden Pathogens an der Pilz-Tier Grenze *Sphaerothecum destruens* Arkush et al., 2003.

REZUMAT: Distribuție revizuită- cinsprezece ani de schimbări în invazia unui pește de apă dulce, *Pseudorasbora parva* (Temminck și Schlegel, 1846) în Turcia.

Scopul prezentei lucrări este revizuirea ariei de distribuție a speciei invazive de apă dulce, *Pseudorasbora parva* (Temminck și Schlegel, 1846) în Turcia, pe baza revizuirii literaturii. După o primă raportare a speciei în râul Meriç din Tracia (partea europeană a Turciei) în 1982, sa răspândit în țară în principal datorită introducerilor antropice accidentale și a fost raportată dintr-un număr total de 66 de bazine de apă. Sunt de asemenea prezentate căi de introducere și modele cronologice de distribuție a speciei. Această informație se crede că este utilă în special pentru conservarea ihtiofaunei endemice. Efectul negativ a murgoiului bălțat, este reprezentat în particular prin introducerea unui patogen eucariot intracelular infecțios emergent la granița fungi-animale, *Sphaerothecum destruens* Arkush et al., 2003.

INTRODUCTION

In general, freshwater ecosystems and its endemic specific fauna are adversely affected by introduction of non-native species, pollution and drought (Marr et al., 2013). Non-native fish species are usually introduced into freshwater ecosystems through transportation, aquaculture and biological control along with fish stocking, fisheries and pet trade (Allan and Flecker, 1993; Maitland, 1995; Ruesink, 2005; Özcan, 2008; Tarkan et al., 2015). In the case of being invasive, non-native fish species have great potential to impact native biota both economically and ecologically (Cucherousset and Olden, 2011).

Turkey has a rich freshwater fish biodiversity with high number of endemic species (Tarkan et al., 2015). In total, 377 species have been reported so far; the majority belongs to the Cyprinidae family (Çiçek et al., 2015). In Turkey, there are approximately 157 endemics (Çiçek et al., 2015) and 30 introduced freshwater fish species being overall establishment success over 60% (Tarkan et al., 2015). One successfully non-indigenous fish species is *Pseudorasbora parva* (Temminck and Schlegel, 1846), which is an invasive species of the European fish fauna that influence native and endemic fishes by generating damages (Curtean-Bănăduc and Bănăduc, 2007-2008; DIAS, 2017; GISD, 2017; NISD, 2017) including in pond fish farming as a strong competitor (Csorbai et al., 2014) and healthy carrier of a deadly pathogen *Sphaerothecum destruens* Arkush et al., 2003 (Gozlan et al., 2005).

Pseudorasbora parva was originally discovered in Nagasaki, Japan and they are also naturally distributed in China and Siberia (Berg, 1949). This species was recorded in Europe in the 1960s; they were possibly introduced through the movement of Chinese carps for fish farming (Gozlan et al., 2010) and the species was reported in Turkey for the first time in 1982 from Meriç River (Thrace – European part of Turkey) (Erk'akan, 1984), then from Aksu River (Anatolia – Asian part of Turkey) in 1994 (Wildekamp et al., 1997). Ekmekçi and Kırankaya (2006) reviewed the distribution of the species in Turkey and reported seven new locations for the species. Since then, several new locations have been recorded for the species except for Eastern part of the country (e.g. Uğurlu and Polat, 2007; İlhan and Balık, 2008; Şaşı and Berber, 2013; Çınar et al., 2013; Bakaç et al., 2017; Gül et al., 2017; Karakuş et al., 2017; Küçük et al., 2018). Since distribution pattern of *Pseudorasbora parva* has not properly been reviewed despite its presence in Turkish inlands for almost four decades and available information on the distribution range is obsolete, we aimed to present current distribution and introduction pathways of the species in Turkey.

MATERIAL AND METHODS

A literature review was performed in Web of Science, and supplemented by Google Scholar, starting with the species name ("*Pseudorasbora parva*" and "topmouth gudgeon") and country of interest ("Turkey") as well as complimentary words ("new", "record", "locality", "occurrence", "distribution", "spread", "range" and their combinations). Also, available journal archives, reports and grey literature were reviewed. All location reports were tabulated and visualized with a table and figure, respectively by enumerating them chronologically. The introduction rate of *Pseudorasbora parva* was calculated as the average number of new locations introduced per decade after Ribeiro et al. (2009).

RESULTS AND DISCUSSION

For Turkish freshwater bodies, *Pseudorasbora parva* is considered one of the most ecologically damaging species that is rapidly spreading and become established (Ercan et al., 2015; Tarkan et al., 2015). Our near-comprehensive literature screening presented that *Pseudorasbora parva* is widely distributed in Turkey, particularly in the regions located in western part of the studied country; Aegean, Mediterranean and Marmara regions (Fig. 1).

The average rate of introduction to Turkey of *Pseudorasbora parva* since the first introduction of the species in early 1980s up to the date is 1.7 per decade. For the period 1990-2020 and 2000-2020 it is 2.2 and 2.9 species per decade (Fig. 2). Although this rate is now almost the same (2.9 vs. 2.8) for the last two decades (i.e. 2000-2010 and 2010-2020), it is likely that the latter would be higher with potential new location reports in next two years until 2020 (Fig. 2). This considerable increase could apparently be attributable to lack of ichthyofaunal surveys and the species' misidentification especially before 2000s where the former is still true for the eastern part of the country (Fig. 1). Indeed, there is a relatively long time (i.e. 12 years) and distance (approximately 900 km) between first (Erk'akan, 1984) and second record (Küçük and İkiz, 2004) of the species but after 2000s, new reports of the species has remarkably increased, mostly from the regions located between first two reported locations (Tab. 1; Fig. 1). The fourth report of the species was in late 1990s from a basin (Sakarya Basin), which is located in between those locations (Ekmekçi, 2000).

Based on the pattern of *Pseudorasbora parva* introductions since the first report in Turkey, it is likely that the actual distribution of the species in its introduced range reflects a "stepping-stone" type of invasion model, which is characterized as "further introduction from initial one" (Gozlan et al., 2010). This is because the major vectors for the introduction of *Pseudorasbora parva* to Turkey have been indicated as government authorized aquaculture and stocking programmes to establish and support cage aquaculture, and commercial fisheries (Tarkan et al., 2015). Hence, the accidental transfer and release of *Pseudorasbora parva* within the translocations of native cyprinids (mainly common carp *Cyprinus carpio*) for aquaculture characterize the primary pathway of *Pseudorasbora parva* introduction into its expanded range in Turkey. Our review of location reports of the species supports this suggestion as it has been reported from distant locations in different times, i.e. does not follow a regular distribution pattern (Tab. 1; Fig. 1). Indeed, second record of *Pseudorasbora parva* in Anatolia after its first report of in Thrace strongly suggests that the expansion of the species by natural ways is not likely, as this freshwater gudgeon species cannot pass two salt water barriers (i.e. İstanbul and Çanakkale straits), which separates European and Asian parts of Turkey. Recent findings of the species in a remote location (i.e. Gökçeada Island) have strengthened this contention (Bakaç et al., 2017).

Figure 1: Updated distribution map of *Pseudorasbora parva* in Turkish inlands by location:

1. Meriç River; 2. Karacaören I-II reservoirs; 3. Aksu River; 4. Kirmir Stream; 5. Kirmir Stream; 6. Kirmir Stream; 7. Topçam Reservoir; 8. Sarıyar Reservoir; 9. Dipsiz-Çine Stream; 10. Gelingülü Reservoir; 11. Gölcük Lake; 12. Yortanlı Stream; 13. Bekdiğin Pond; 14. Gelingülü Reservoir; 15. Ağaçköy Stream, Felek Stream and Enne Reservoir; 16. Uluabat Lake; 17. Kemer Reservoir; 18. Topçam Reservoir; 19. Sekiören Pond; 20. Pazarlar Pond; 21. Doğluşah Pond; 22. Söğüt Reservoir; 23. Altınbaş Pond; 24. Göğem Pond; 25. Enne Reservoir; 26. Kayaboğazı Reservoir; 27. Çatören Reservoir; 28. Kunduzlar Reservoir; 29. Erenköy Pond; 30. Meyil Lake; 31. Evri Stream; 32. Günyüzü II Pond; 33. Koçaş Pond; 34. Mercan Pond; 35. Bahçeçik Pond; 36. Kaymaz Reservoir; 37. Yenice Reservoir; 38. Gökçekaya Reservoir; 39. Eğirdir Lake; 40. Küçükelmali Pond; 41. Kızıldamlar Reservoir; 42. Dodurga Reservoir; 43. Dumlupınar Pond; 44. Çavdarhisar Pond; 45. Porsuk River; 46. Akın Creek; 47. Marmara Lake; 48. Bayraktar Reservoir; 49. Kirazoğlu Reservoir; 50. Davuldere Reservoir; 51. Ula Reservoir; 52. Onaç Reservoir; 53. Mogan Lake; 54. Gökçeada Reservoir; 55. Demirköprü Reservoir; 56. Afşar Reservoir; 57. Gördes Stream; 58. Marmara Lake; 59. Gediz River; 60. Demirci Stream; 61. Kemerdağları Drainage Channel; 62. Gödet Creek; 63. Gödet Reservoir; 64. Deliçay Reservoir; 65. İbrala Reservoir; 66. Ayrançı Reservoir; for details see table 1.

According to Hanel et al. (2011), *Pseudorasbora parva* can establish abundant populations in stagnant bodies of water compared to running waters. This is in line with our review showing that out of 66 water bodies, 50 were stagnant water (lake, reservoir and pond) and only 16 were running water (creek, stream and river) (Tab. 1). Also, reviewed resources confirmed that it become established more abundantly in still waters. High phenotypic plasticity in fitness related traits such as growth, early maturity, fecundity, reproductive behaviour (paternal care) and the ability to cope with novel pathogens has predisposed the *Pseudorasbora parva* to be a strong invader (Gozlan et al., 2010). Recently, *Pseudorasbora parva* in Turkey has been shown to grow better than both native and non-native populations (Akbaş et al., 2015). Further, *Pseudorasbora parva* was considered as a serious threat to native and endemic fish species in several water bodies of Turkey that have high biodiversity richness (Ekmekçi and Kırankaya, 2006; Özcan, 2008; Polat et al., 2011).

Notably, the most compelling issue regarding the invasion of *Pseudorasbora parva* is that it is a healthy carrier of a rosette agent *Sphareothecum destruens*, a generalist pathogen on the animal-fungal boundary (Gozlan et al., 2005). After the experimental evidence of the pathogen in *Pseudorasbora parva* (Gozlan et al., 2005), first field evidence was provided from Turkey (Sarıçay River, Milas, SE Turkey) (Ercan et al., 2015), which also proved its introduction via *Pseudorasbora parva* to sea bass farms and linking the pathogen to severe declines in threatened European endemic freshwater fishes (i.e. 80% to 90% mortalities).

Table 1: Chronological list of reported locations of *Pseudorasbora parva* in Turkish inlands.

No.	References	Location	Report Date
1.	Erk'akan, 1984	Meric River-Üpsala/ Edirne	16 September 1982
2.	Küçük and İkiz, 2004	Karacaören I-II Reservoirs/Aksu River/Isparta-Burdur	November 1994-October 1996/September 2002- August 2003
3.	Wildekamp et al., 1997	Aksu River/ Antalya	29-30 July 1996
4.	Ekmekçi, 2000	Sakarya Kirmir Stream	1999
5.	Ekmekçi, 2000	Kirmir Stream	1998
6.	Ekmekçi and Kırnkaya, 2006	Kirmir Stream	January 1998
7.	Şaşı and Balık, 2003	Topçam Reservoir/ Aydın	June 1999-June 2000
8.	Ekmekçi and Kırnkaya, 2006	Sarıyar Reservoir	November 1999
9.	Barlas and Dirican, 2004	Dipsiz-Çine Stream/ Aydın	November 1999 and February 2001
10.	Ekmekçi and Kırnkaya, 2006	Gelingülü Reservoir, Kızılırmak/Yozgat	June/2002-December 2004
11.	Yeğen et al., 2015	Gölçük Lake/ Isparta	17 May 2003
12.	Ekmekçi and Kırnkaya, 2006	Yortanlı Stream/Bakırçay/ İzmir	–
13.	Uğurlu and Polat, 2007	Bekdiğin Pond/ Samsun	June 2003-September 2005
14.	Yalçın-Özdilek et al., 2013	Gelingüllü Reservoir/ Yozgat	Summer 2003 and Summer 2005
15.	İlhan and Balık, 2008	Ağaçköy Stream – Felek Stream, Enne Reservoir/Kütahya	Summer 2004 and 2005
16.	Çınar et al., 2013	Uluabat Lake (Apolyont)/Bursa	January 2006 and December 2006

Table 1 (continued): Chronological list of reported locations of *Pseudorasbora parva* in Turkish inlands.

17.	Şaşı and Berber, 2013	Kemer Reservoir/ Aydın	April 2007 to February 2008
18.	Şaşı and Berber, 2013	Topçam Reservoir/ Aydın	April 2007 to February 2008
19.	Yeğen et al., 2015	Sekiören Pond/ Kütahya	03 May 2007
20.	Yeğen et al., 2015	Pazarlar Pond/ Kütahya	22 May 2007
21.	Yeğen et al., 2015	Doğluşah Pond/ Kütahya	24 May 2007
22.	Yeğen et al., 2015	Söğüt Reservoir/ Kütahya	24 May 2007
23.	Yeğen et al., 2015	Altınbaş Pond/ Uşak	14 June 2007
24.	Yeğen et al., 2015	Göğem Pond/ Uşak	14 June 2007
25.	Yeğen et al., 2015	Enne Reservoir/ Kütahya	28 August 2007
26.	Yeğen et al., 2015	Kayaboğazı Reservoir/ Kütahya	30 August 2007
27.	Yeğen et al., 2015	Çatören Reservoir/ Eskişehir	24 October 2008
28.	Yeğen et al., 2015	Kunduzlar Reservoir/ Eskişehir	24 October 2008
29.	Yeğen et al., 2015	Erenköy Pond/ Eskişehir	01 October 2008
30.	Özuluğ et al., 2013	Meyil Lake (Konya)	2008
31.	Özuluğ et al., 2013	Evri Stream (Kahramanmaraş)	2008
32.	Yeğen et al., 2015	Günyüzü II Pond/ Eskişehir	28 April 2009
33.	Yeğen et al., 2015	Koçaş II Pond/ Eskişehir	28 April 2009
34.	Yeğen et al., 2015	Mercan Pond/ Eskişehir	29 April 2009
35.	Yeğen et al., 2015	Bahçeçik Pond/ Eskişehir	29 April 2009
36.	Yeğen et al., 2015	Kaymaz Reservoir/ Eskişehir	30 April 2009
37.	Yeğen et al., 2015	Yenice Reservoir/ Eskişehir	26 May 2009

Table 1 (continued): Chronological list of reported locations of *Pseudorasbora parva* in Turkish inlands.

38.	Yeğen et al., 2015	Gökçekaya Reservoir/ Eskişehir	27 May 2009
39.	Yağcı et al., 2014	Eğirdir Lake/ Isparta	March 2010 and June 2011
40.	Yeğen et al., 2015	Küçükemali Pond/ Bilecik	06 May 2010
41.	Yeğen et al., 2015	Kızıldamlar Reservoir/ Bilecik	06 July 2010
42.	Yeğen et al., 2015	Dodurga Reservoir/ Bilecik	18 August 2010
43.	Yeğen et al., 2015	Dumlupınar Pond/ Kütahya	19 August 2010
44.	Yeğen et al., 2015	Çavdarhisar Reservoir/ Kütahya	19 August 2010
45.	Yeğen et al., 2015	Porsuk River/ Eskişehir	16 August 2011
46.	Yeğen et al., 2015	Akın Creek/ Eskişehir	13 September 2011
47.	İlhan and Sarı, 2013	Marmara Lake/ Manisa	March 2012-February 2013
48.	Keskin et al., 2013	Bayraktar Reservoir/ -İzmit	2012
49.	Keskin et al., 2013	Kirazoglu Reservoir/ -İzmit	2012
50.	Keskin et al., 2013	Davuldere Reservoir/ -İzmit	2012
51.	Keskin et al., 2013	Ula Reservoir/ -Muğla	2012
52.	Yeğen et al., 2015	Onaç Reservoir/ Burdur	02 October 2013
53.	Gül et al., 2017	Mogan Lake/ Ankara	January-December 2014
54.	Bakaç et al., 2017	Gökçeada Reservoir/ Çanakkale	08 June 2016
55.	Karakuş et al., 2017	Demirköprü Reservoir/Manisa	March-August 2017
56.	Karakuş et al., 2017	Afşar Reservoir/ Manisa	March-August 2017
57.	Karakuş et al., 2017	Gördes Stream/ Manisa	March-August 2017

Table 1 (continued): Chronological list of reported locations of *Pseudorasbora parva* in Turkish inlands.

58.	Karakuş et al., 2017	Marmara Lake/ Manisa	March-August 2017
59.	Karakuş et al., 2017	Gediz River/ Manisa	March-August 2017
60.	Karakuş et al., 2017	Demirci Stream/ Manisa	March-August 2017
61.	Karakuş et al., 2017	Kemerdağları Drainage Channel/Manisa	March-August 2017
62.	Küçük et al., 2018	Gödet Creek/ Karaman	2015-2017
63.	Küçük et al., 2018	Gödet Reservoir/ Karaman	2015-2017
64.	Küçük et al., 2018	Deliçay Reservoir/ Karaman	2015-2017
65.	Küçük et al., 2018	İbrala Reservoir/ Karaman	2015-2017
66.	Küçük et al., 2018	Ayrancı Reservoir/ Karaman	2015-2017

Figure 2: Temporal pattern of introduction of *Pseudorasbora parva* into Turkish watersheds.

Cumulative number of the species introduction (left axis)
and the rate of the species introduction per decade (right axis) is presented.

CONCLUSIONS

Overall, our near comprehensive review points out rapid and wide spread distribution of *Pseudorasbora parva* in Turkey and suggests that it would increasingly continue to spread in the future. It is most probable that the number of new records of the species in Turkey will increase with more frequent ichthyofaunal researches especially in the eastern part of Turkey.

To this end, *Pseudorasbora parva* introductions and related infectious diseases should constantly be monitored and necessary management actions with robust risk assessments should follow given rich native and endemic freshwater biodiversity in Turkey.

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