



Efficiency and Suitability of the Fish Passages of River Ceyhan, Turkey

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ABSTRACT

The efficiencies of the two fish passages of River Ceyhan (Turkey) were investigated by using trap catches, external tags (T-bar anchor tags), PIT telemetry and radio telemetry. According to the results of the study, the pool and weir type fish passage were not effective; no fish entered the trap in this fish passage. Further, it was observed that none of the 50 external tagged fishes, 44 PIT-tagged fishes, and 47 radio-tagged fishes passed through this fish passage. A total of 900 *Capoeta damascina* and 520 *Alburnus adanensis* entered the trap installed in the vertical slot fish passage. A relationship was found between the gender ratio of the migratory *C. damascina* and their migration times. Fish passage performance was different according to the applications. These differences in fish passage success among the applications originated from the sizes of the tagged fish. Because the sizes of the radio-tagged fish were much larger than that of the external tagged fish and PIT-tagged fish so the success of the fish passage according to the radio telemetry was estimated higher than that of the other applications. The further passing ratio of the fish over 20 cm in length was higher than that of the small individuals.

Keywords: Fish passage, fish migration, efficiency, trap, telemetry

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Ceyhan Nehri'ndeki (Türkiye) Balık Geçitlerinin Etkinlikleri ve Uygunlukları

Öz: Ceyhan Nehir havzasında bulunan iki balık geçidinin etkinlikleri trap uygulaması, dıştan takma markalamalar (T-bar anchor tag), PIT telemetri ve radio telemetri yöntemleri ile incelenmiştir. Çalışma sonuçlarına göre havuzlu ve orifisli balık geçidine yerleştirilen trapta hiç bir balık tespit edilememiş olduğundan bu balık geçidinin etkinliğinin olmadığı belirlenmiştir. Ayrıca 50 adet dıştan takma marka, 44 adet PIT marka ve 47 adet radio markası taşıyan balıklardan hiç birinin bu balık geçidinden geçmediği görülmüştür. Dikey yarıklı balık geçidine yerleştirilen trapta ise toplam 900 *Capoeta damascina* ve 520 *Alburnus adanensis* tespit edilmiştir. Göç yapan *C. damascina* bireylerinin cinsiyet oranları ile göç zamanları arasında bir ilişki tespit edilmiştir. Uygulanan yöntemlere göre balık geçidinin performansı farklılık göstermiştir. Bu farklılık markalanan balıkların boylarının farklı olmasından kaynaklanmıştır. Çünkü radyo taglarla markalanan balıkların boyları PIT taglarla ve dıştan takma markalarla markalanan balıklardan daha büyüktü ve bu nedenle radyo telemetri yöntemine göre hesaplanan balık geçidi performansı diğer yöntemlere göre daha yüksek bulunmuştur. Ayrıca, 20 cm'den büyük balıkların balık geçidinden geçme performansı küçük balıklara göre daha yüksek olmuştur.

Anahtar kelimeler: Balık geçidi, balık göçü, etkinlik, trap, telemetri

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Introduction

River habitats that have important roles for the sustainability of fish populations are negatively affected by engineering structures such as dams and hydropower plants built on rivers (Larinier 2000; Marmulla 2001; Jackson and Marmulla 2001). Hydropower plants have to be environmentally friendly; hydroelectric power plant projects should

consider fish migrations in river basins. A suitable fish passage ensures the migration of fish between zones of the feeding and spawning. Otherwise, fish stocks decline, certain fish species become extinct or fragmented populations come into the picture (Larinier 2000; Roscoe and Hinch 2010). Various designs of fish passages have been developed in the past to enable fish to pass barriers and to minimize

the impacts of the obstructions (Roscoe and Hinch 2010). The first known attempts to build fish passages were older than the development of hydropower itself and were constructed in Europe more than 300 years ago (Clay 1995; Calles and Greenberg 2005; Katopodis and Williams 2012). First written documents about fish passages goes back to 1870s (Worrall 1874; Rogers 1892; Cheney 1898; Buck 1906, 1913; Dyche 1912; Prince 1914; Larinier et al. 2002; Roscoe and Hinch 2010; Bunt et al. 2012; Williams et al. 2012; Brown et al. 2013).

The most important impacts of the construction of reservoirs are on the ichthyofauna, especially on migratory fish. The impacts are due to the interception of migratory routes, alteration of the hydrological regime, and reduction of spawning and nursery habitats (Wagner et al. 2012; Agostinho et al. 2004). The observations for the fish passages in Turkey have shown that they were constructed without proper assessment and usage of basic scientific knowledge on the fish species of concern. Although more than 370 fish species inhabit Turkish inland waters (Kuru et al. 2014), there is no proper inventory for migratory fish species. Contemporary literature does not provide proper information on habitat usages and hydrological requirements of inland water fish in Turkey. However, it is a well-known fact that an effective fish passage design requires extensive integration of biological and hydrological data in addition to other physical data (Castro-Santos et al. 2009).

State-owned large dams have been built in Turkey within the past 60 years and almost none has proper fish passages. *Anguilla anguilla* has disappeared in the inland sections of Turkey. It only inhabits lower sections of rivers downstream of dams with lowest altitudes and coastal lagoons since migrations of fish were not ensured by large dam projects. Sturgeon in the Black Sea Region is also almost extinct because of the lack of fish passages near dam structures. The first fish passage of Turkey was built on Seyhan Regulator in 1939 and the second one was built on Emiralem Regulator in 1944. These passages and other 35 passages were been constructed by the General Directorate of State Hydraulic Works (DSI 2013). All these fish passages were built on the small regulators and no fish passage is present on other 596 large dams. Additionally, more than 1250 small scale and relatively new hydroelectric power plants have been erected by private companies since 2001. The Turkish Fisheries Code no: 1380 requires these small scale hydroelectric power plants belonging to the private sector have to have fish passages. These fish passages are often pool and weir, and vertical slot type rather than Denil type. Unfortunately, there is no database

as related to the effectiveness of present fish passages. The number of studies on the evaluation of fish passages in the World reached to considerable level (96 studies from America, Europe, and Australia) and 76% of the articles in journals were published between 1999 and 2008 (Roscoe and Hinch 2010). Nearly all studies focused on efficiency questions while some of them included mechanisms, consequences, and physiology. So far, a few studies have been conducted on the evaluation of the effectiveness of fish passages in Turkey (Alp et al. 2018; Kucukali et al. 2019). Some telemetry methods such as PIT telemetry, radio telemetry, and video monitoring systems have been applied to investigate the efficiency of fish passages (Castro-Santos et al. 1996; Lucas et al. 1999; Riley et al. 2010; Roscoe and Hinch 2010).

Turkish inland waters have more than 370 fish species and about more than 100 of them are endemic (Kuru et al. 2014). From these species, two of them (sturgeon and Black Sea trout) are anadromous and also one species (*Anguilla anguilla*) is catadromous. The contemporary literature does not offer enough information about the potamodromous species and their migrations. Further, there is a lack of knowledge about the effects of hydropower applications on the potamodromous species.

The effectiveness of the fish passages in two streams of River Ceyhan (Turkey) was studied to collect data about the fish species and passage performances within the scope of this specific research. The results of the study may hopefully be used to apply more effective fish conservation strategies by designing better and more suitable fish passages to reduce the ecological problems created by hydropower plants. To achieve the goal of the research, following enlisted data were obtained about the fish passed through the fish passages; a) migratory fish species, b) the number of the migrated fishes, c) the sizes of the migrated fish, d) genders of the migrated fishes e) migration seasons and migration durations and f) the performances of the fish passages.

Materials and Methods

Study site

Ceyhan River Basin is in the Eastern Mediterranean region of Turkey and is bordered by Seyhan Basin in the west and northwest, Asi Basin in the south and Fırat Basin in the east and northeast. The river drains into the Mediterranean Sea in the south. Ceyhan River Basin area is 20670 km² and its mean annual flow volume is 7.18 billion cubic meters. This corresponds to 4% of the total river discharge to Turkey (Agrin Co. Ltd. 1999; Tanrıverdi et al. 2010).

A total of 9 large dams belonging to the state were built in Ceyhan River Basin and none of these has a fish passage (Figure 1). *Anguilla anguilla* has been extinct in the middle and upper sections of the Ceyhan River basin (Kara et al. 2010). In addition to these large dams, a total of 50 small scale hydropower plants were constructed by private companies in Ceyhan River Basin (Figure 1). Only 16 of these small-scale hydropower plants have fish passage facilities. They are pool and weir type (5 fish passages), vertical slot type (10 fish passages) and Denil type (1 fish passage). Fish fauna of the Ceyhan River

consists of 20 species belonging to 10 families (Kara et al. 2010).

A vertical slot type fish passage from Tekir Stream and a pool and weir type fish passage from Fırnız Stream of Ceyhan River were studied in this study. Vertical slot fish passage was 126 m in length and 14.10 m in height with a slope of 11.19%. It includes 63 pools and its pool dimensions were 140 by 200 cm with two water inlets for fish exit from upstream. Pool and weir fish passage was 25.43 m in length and 4.5 m in height with a slope of 17.70%. It has 16 pools and one water inlet from the upstream site and orifices sizes were 30 by 30 cm.

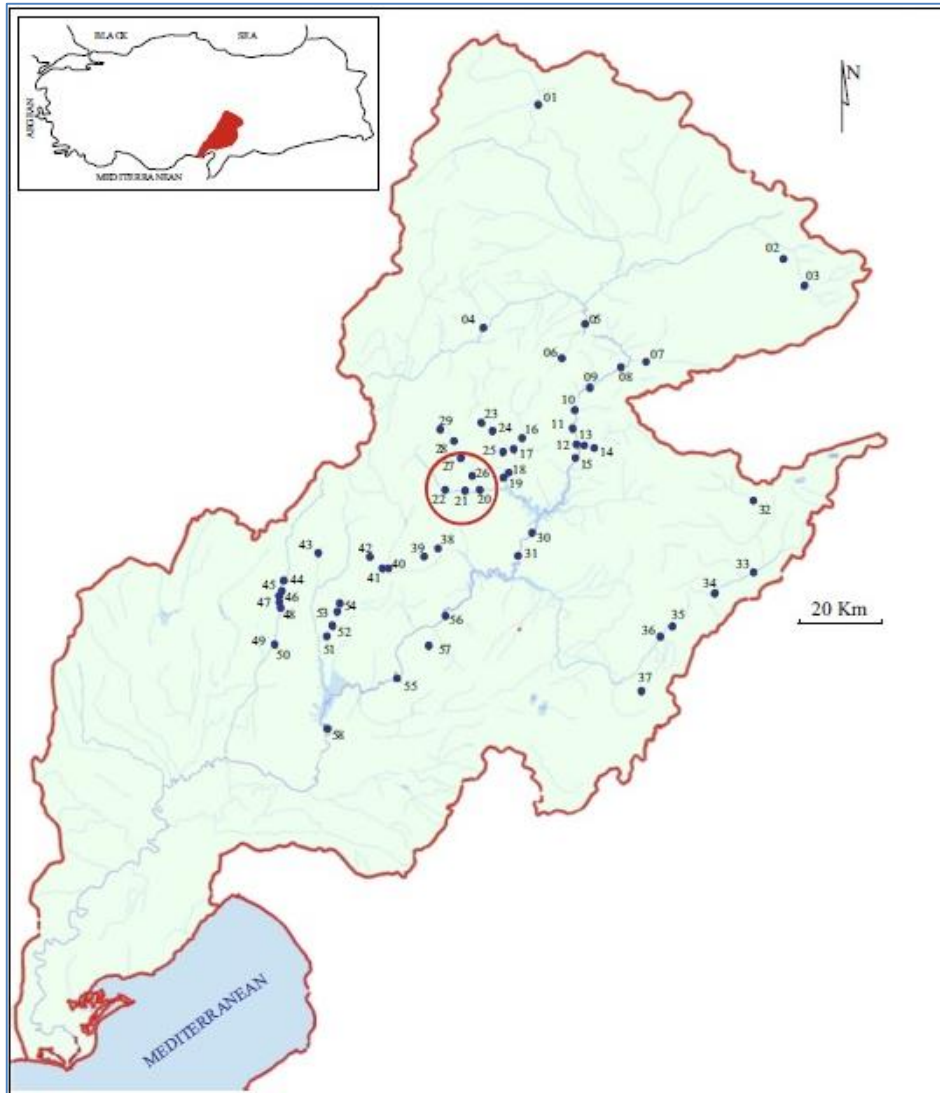


Figure 1. Ceyhan River Basin and distribution of hydropower plants.

*Studied streams are circled by red line:(1. Karakuz HES, 2. Söğütlü 1 HES, 3. Kantarma HES, 4. Adatepe HES, 5. Dağdelen HES, 6. Köyobası HES, 7. Uzuntepe HES, 8. Kandil 1 HES, 9.(Kandil 2 HES, 10. Sarıgüzel 1 HES, 11. Sarıgüzel 2 HES, 12. Çakmak 2 HES, 13. Söğütlü HES, 14. Çakmak 1 HES, 15. Hacınnoğlu HES, 16. Okkayası ve Şehitlik HES, 17. Süleymanlı HES, 18. Zeytin HES, 19. Kozak HES, 20. Suçatı HES, 21. Fırnız HES, 22. Aşağı Fırnız HES, 23. Sisne HES, 24. Sivritaş HES,25. Avcılar HES, 26. Çamlık HES, 27. Çataloluk HES, 28. Kısık HES, 29. Üçkaya HES, 30. Menzelet HES,31. Kılavuzlu HES, 32. Aksu HES, 33. Akpınar HES, 34. Nur HES, 35. Kartalkaya HES, 36. Kesme HES,37. Yeşil HES, 38. Torlar HES, 39. Gökgedik HES, 40. Kale HES, 41. Karasu HES, 42. DeğirmenüstüHES, 43. Teytur HES, 44. Tahta HES, 45. Karapınar HES, 46. Andırın HES, 47. Kargılık HES, 48. Bulgurkaya HES, 49. Tayfun Kanal HES, 50. Damlasu HES, 51. Poyraz HES, 52. Sazak HES, 53. Çatak HES, 54. Güneşli HES, 55. Berke (Değirmen) HES, 56. Sır HES, 57. Güvercin HES, 58. Aslantas HES)

Determination of the migratory species

Traps were installed into fish passages to determine fish species and the number of the individuals passing through the fish passage, their sizes, genders and migration periods. The size of the traps was determined considering the dimensions of the fish passages and they were made of a metal frame box including a cone and 0.5 cm stretched mesh size. Traps were set up into third pools at the top side of the fish passage so that fish could not pass through the edges of the trap. They were controlled routinely and the caught fish with traps were taken into a tank and then they were anesthetized with 2-phenoxy ethanol. For each species, the total number and the genders of the fishes were determined; their lengths were measured. Following recovery and gaining swimming ability, they were released into the upper pool of the fish passage. A Hobo Onset sensor was installed into the fish passage and the water temperature was recorded for each half an hour.

Evaluation of efficiencies of fish passages

External tags (T-Bar anchor tags), PIT telemetry (passive integrated transponder (PIT) tags) and radio telemetry methods were the adopted methods to achieve the goals of the research.

a) External tag application

The fish were caught by electro shocker at downstream of fish passage. They were anesthetized with 2-phenoxy ethanol, measured and tagged with T-Bar anchor tags from the base of dorsal fin using a tag gun. A total of 172 fishes (122 fish in Tekir Stream and 50 fish in Fırnız Stream) were tagged with T-Bar anchor tags. The traps into the fish passages were controlled routinely and T-Bar anchor tagged fish into the traps were recorded, counted and then released to the upper pool of the fish passage.

b) PIT telemetry

Fishes were caught by electro shocker at downstream of fish passage and they were anesthetized with 2-phenoxy ethanol and then measured. A total of 200 fish (156 fish in Tekir Stream and 44 fish in Fırnız Stream) was tagged with a passive integrated transponder (PIT) tags by a tag gun and released to the downstream of fish passage. All PIT tags were HPT 12 model tags and they were 12 mm in length and with 134.2 kHz. To detect PIT-tagged fish passed through the fish passage, a square antenna (80x80 cm in dimension) was placed into the fish passage and the system was linked to an HPR Reader system. The detection range for a standard 12 mm PIT tag was reported to be 15.2-25.4 cm from the antenna (Reagan et al. 2005). All PIT telemetry equipment was produced by BIOMARK Company (Boise-Idaho, USA).

c) Radio telemetry

A total of 73 fishes (47 fishes in Fırnız Stream and 26 fishes in Tekir Stream) caught by electro shocker from downstream of fish passages were tagged with cylindrical radio transmitters (Lotek Wireless Inc, Model MST-930) with the sizes of 26 mm length by 9.5 mm width and with 4.5 g weight. The expected battery life of the transmitters was 266 days with a signal transmit at 5 seconds interval for 24 hours. However, the battery life of the transmitters was extended to 385 days by the programming of “on” 12 hours / “off” 12 hours. The frequencies of the transmitters used were preferred between 149.420 and 150.320 MHz. Each transmitter had a unique code that allowed for individual identification.

The fish were anesthetized with 2-phenoxy ethanol (0.5 ml l⁻¹ water), measured and transmitters were surgically implanted into fishes on a V-shaped surgery table. During the surgery operation, the lower anesthetic concentration of water (0.4 ml l⁻¹ water) was given from the mouth of the fish by a pipe so that the gills were constantly kept wet. The transmitters were inserted into the body cavity through a ventral 10 to 15 mm incision and then it was closed with three sutures. The antenna was pushed through the body wall using a hollow needle (Thorsteinsson 2002; Ramstad and Woody 2003; Fredrich et al. 2003; Jepsen et al. 2005; Lucas and Bubb 2005; Thorstad et al. 2013). Radio tagged fish were tracked by Lotek SRX 400 radio receiver and yagi antenna, and the tagged fish passed through the fish passage were recorded.

Results

Migratory fish species ascending through the fish passage

Trap placement

Traps were installed into fish passages in Fırnız Stream and Tekir Stream on the 20th of April 2012 and 2013, respectively. Traps were operated during 84 days in 2012 between April 20th and July 13th; during 79 days in 2013 between April 20th and July 8th. No fish have been detected in traps installed into the pool and weir fish passage in Fırnız Stream, for the above-mentioned periods.

A total of 428 *Capoeta damascina* and 262 *Alburnus adanensis* individuals ascended vertical slot fish passage in Tekir Stream in 2012 and they migrated towards upstream (Table 1). In 2013, 472 *C. damascina* and 258 *A. adanensis* ascended the same fish passage and migrated towards the upstream. Upstream migration of *C. damascina* lasted 63 days in 2012, between May 1st and July 7th, while it was 46 days in 2013, between May 1st and June 15th. Upstream migration of *A. adanensis*

continued during 56 days in 2012, between May 8th and July 3rd, and during 53 days in 2013 between May 1st and June 23rd.

The major fish migration of both species occurred during the end of May and the beginning of June.

Table 1. The number of the fish into the traps in vertical slot fish passage and their sizes and gender ratios according to species and dates.

Date	<i>Capoeta damascina</i>			<i>Alburnus adanensis</i>		
	N	Total length (cm)	Male-Female (individual)	N	Total length (cm)	Water temperature (°C) Range (mean±SD)
April 01, 2012	12	21.9±2.95	10-2	0		
May 08, 2012	47	20.6±2.08	35-12	8	15.7±1.83	
May 21, 2012	165	22.7±3.46	81-84	42	15.4±1.59	
June 06, 2012	97	18.9±3.50	39-58	87	14.1±1.45	
June 20, 2012	64	19.2±2.33	21-43	51	14.6±1.36	
July 03, 2012	43	18.9±1.42	12-31	74	14.8±1.47	
July 13, 2012	0			0		
Total (Range)	428	20.9±3.77 (13.0-43.0)	198-230	262	14.7±1.56 (9.0-22.9)	
April 04, 2013	0			0		10.2-12.2 (10.7±0.58)
April 23, 2013	0			0		11.0-14.1 (12.0±0.77)
April 28, 2013	0			0		12.6-16.4 (14.1±1.06)
May 01, 2013	24	18.5±2.82	21-3	18	14.0±1.44	12.2-16.8 (14.0±0.85)
May 06, 2013	54	19.1±2.54	33-21	5	16.2±2.28	11.0-17.5 (13.6±1.54)
May 17, 2013	145	19.7±2.81	61-84	18	16.6±2.45	11.0-19.4 (15.6±1.68)
June 06, 2013	231	19.4±5.02	67-164	185	15.8±2.06	14.5-19.4 (17.2±0.87)
June 15, 2013	18	18.6±3.01	5-13	27	16.8±2.65	16.4-21.7 (18.7±0.87)
June 23, 2013	0			5	15.9±2.64	18.3-22.3 (19.1±0.83)
July 08, 2013	0					
Total (Range)	472	19.4±2.98 (11.2-39.8)	187-285	258	15.8±1.43 (10.0-19.4)	

The total lengths of *C. damascina* ascending fish passage varied between 13 to 43 cm with a mean of 20.9±3.77 cm in 2012. The range was 11.2 to 39.8 cm with a mean of 19.4±2.98 cm in 2013 (Figure 2). The total lengths of

A. adanensis ascending the fish passage showed a variation between 9.0 and 22.9 cm with a mean of 14.7±1.56 in 2012. The range was 10.0 to 19.4 cm with a mean of 15.8±1.43 cm in 2013 (Figure 2).

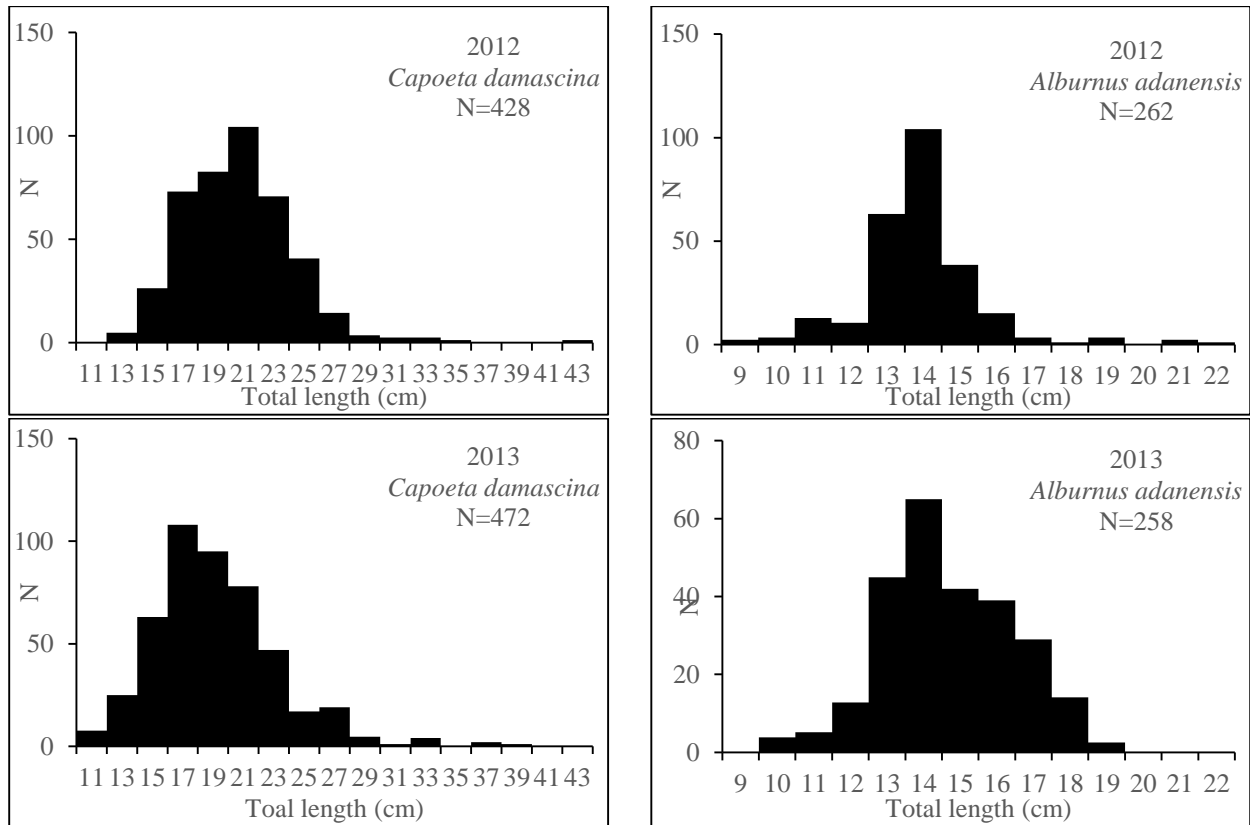


Figure 2. The length-frequency distribution of *Capoeta damascina* and *Alburnus adanensis* into the trap in vertical slot fish passage in 2012 and 2013.

The majority of the *C. damascina* were male individuals in the early days of the migration while towards the end of migration the rate of the males decreased, and the majority of the migratory individuals were females (Table 1). A relationship

was developed between the gender ratio of *C. damascina* individuals and the migration time (in days) with a coefficient of determination = $R^2=0.97$ in 2012. R^2 was 0.93 for the developed relationship for 2013 (Figure 3).

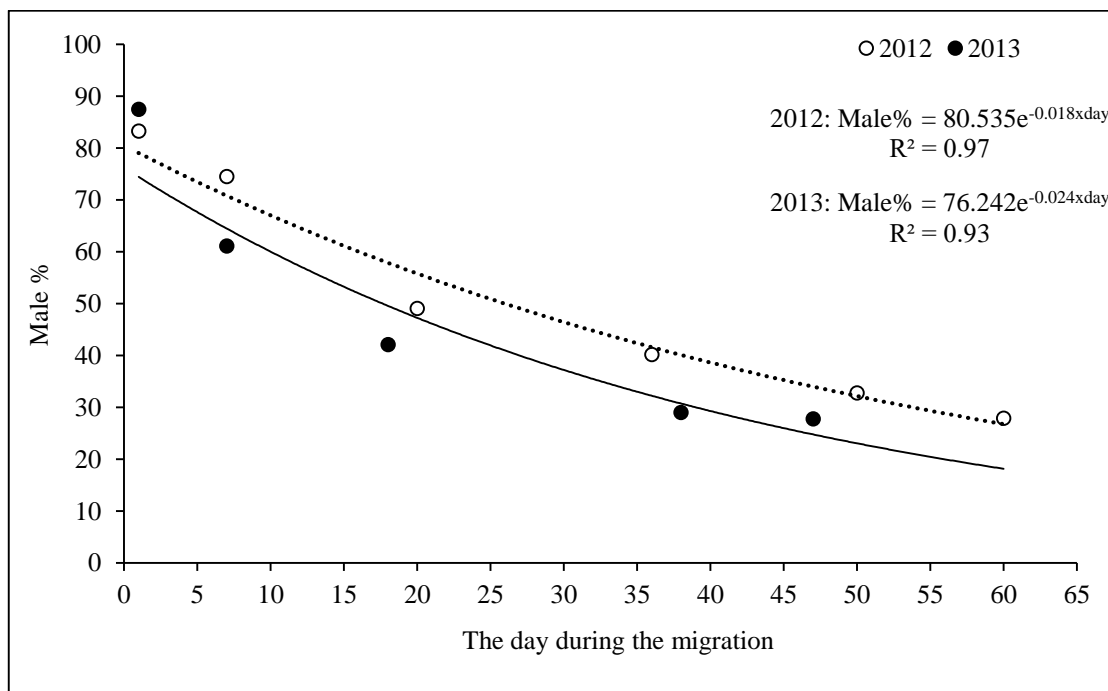


Figure 3. The gender ratios of *Capoeta damascina* obtained from the trap in the vertical slot fish passage according to the date in 2012 and 2013

Water temperature in the fish passage varied from 4.6 to 24.8°C with a mean of 13.2 °C on April 16th of 2013 and on May 10th of 2014. Water temperature varied from 12.2 to 22.3°C during the migration period (Table 1) and the majority of the migration took place with temperatures between 15 and 17 °C.

The efficiency of the fish passages

a) External tagging (T-Bar anchor tags)

A total of 122 *C. damascina* in Tekir Stream and 50 *C. damascina* in Fırnız Stream were tagged with T-bar anchor tags. The total lengths of the tagged fish in Fırnız Stream varied from 14.8 to 39.6 cm with a mean of 23.6±2.97 cm and none of these tagged fish passed through fish passage of Fırnız Stream. The total lengths of T-bar anchor tagged fish in Tekir Stream varied from 13.0 and 26.5 cm with a mean of 19.8±2.75 cm (Figure 4).

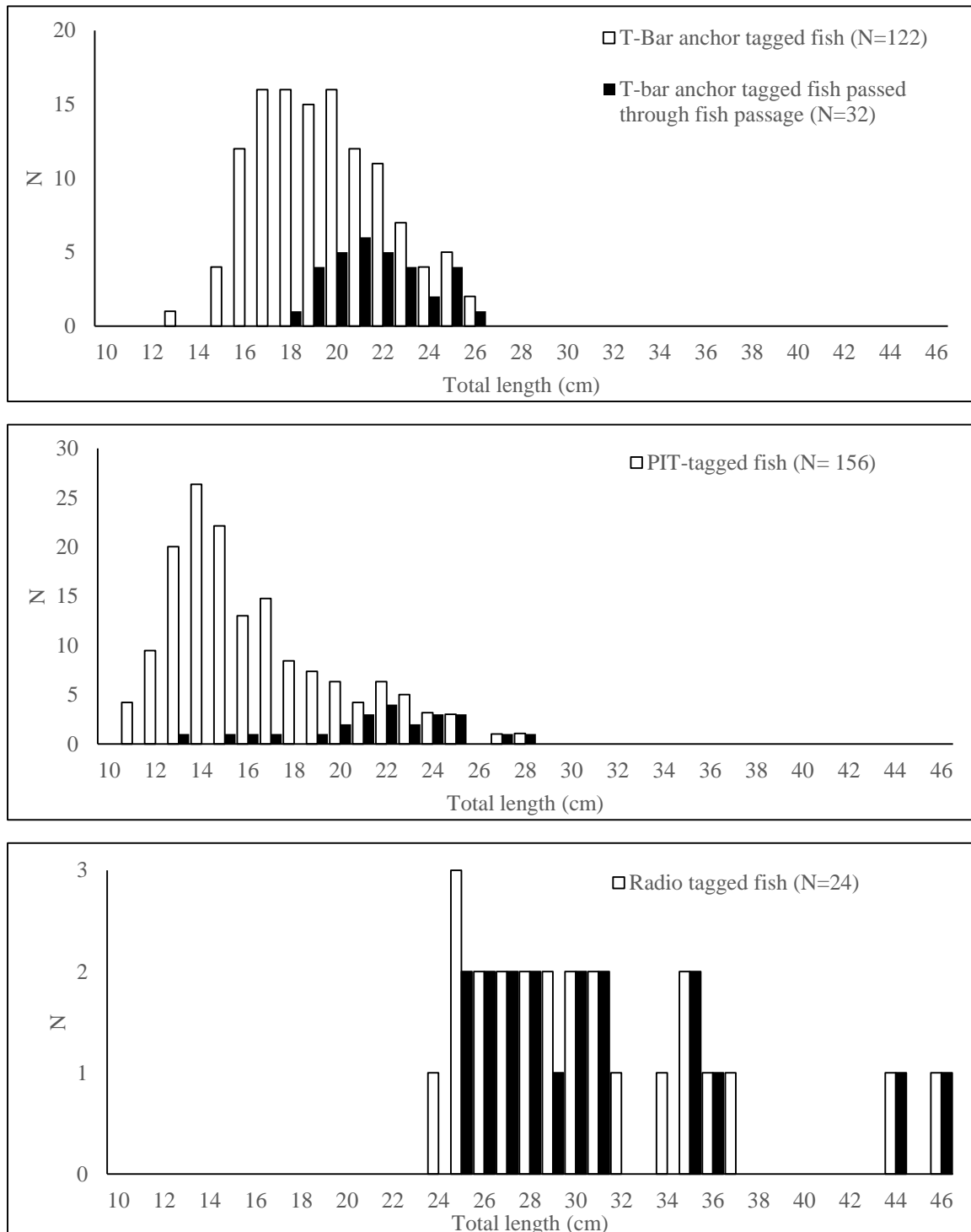


Figure 4. The length-frequency distribution of the tagged *Capoeta damascina* in Tekir Stream.

Of the 122 T-bar anchor tagged fishes, 32 individuals ascended vertical slot fish passage in Tekir Stream corresponding to the ratio of 26.2%. A total of 57 individuals from the 122 tagged *C. damascina* were over 20 cm in length and 27 of these (corresponding to 47.4%) ascended fish passage.

The rate of the passing of small fish through the fish passage was lower than that of the larger ones. The total lengths of the fish ascending the fish passage varied from 18.6 to 26.0 cm with a mean of 22.1 ± 2.10 cm. The total length of the fish that didn't pass through fish passage varied from 13.0 to 26.5 cm with a mean of 19.0 ± 2.49 cm. The total length of the fish passed through the fish passage differed from the length of the fish that didn't pass the fish passage ($t=6.343$, $df=120$; $p=0.000$).

b) PIT telemetry

A total of 200 *C. damascina* were tagged with PIT tags. A total of 156 of them were from Tekir Stream and 44 of them were from Fırnız Stream. The lengths of the PIT-tagged fish in Fırnız Stream varied from 13.4 to 41.1 cm with a mean 22.8 ± 3.12 cm. None of these fish passed through the pool and weir fish passage in Fırnız Stream. PIT tagged *C. damascina* individuals started to ascend the

vertical slot fish passage in Tekir Stream 10 days after tagging and the migration lasted 47 days between May 5th and June 21st, 2014. The majority of the PIT-tagged fish passed through the fish passage between 03 A.M. to 06 A.M. during the early hours of the morning in May (Table 2). The total length of the PIT-tagged fish in Tekir Stream varied from 11.3 and 28.3 cm with a mean of 16.9 ± 3.71 cm (Figure 4). A total of 24 of the 156 PIT-tagged fish ascended vertical slot fish passage in Tekir Stream. The ratio of the fish ascending the fish passage was 15.4%. The total lengths of PIT-tagged fish ascending fish passage showed a variation in between 13.7 and 28.3 cm with a mean of 22.0 ± 3.65 cms. The majority of PIT-tagged fish passing through the fish passage was over 20 cm in length. About 30 individuals of 156 PIT tagged fish were over 20 cm in length and 19 of these 30 fish (corresponding to 63.3%) passed through the fish passage. Statistics indicate that the total lengths of the tagged fish passed through fish passage were not the same as the lengths of the tagged fish that didn't pass the passage ($t=9.061$, $df=154$; $p=0.000$). The passing ratio of large fish through the fish passage was greater than that of the small ones for PIT-tagged fish, as in the case of external-tagged fish.

Table 2. PIT-tagged *Capoeta damascina* passing through the vertical slot fish passage in Tekir Stream and their size and passing time.

Code of the PIT-tag	Total length (cm)	Tagging date	Passing date	Passing time at:
989 002 0007 39977	20.0	April 25, 2014	May 5, 2014	13.11.13
989 002 0007 86586	24.1	April 25, 2014	May 7, 2014	03.38.36
989 002 0007 07037	19.4	April 25, 2014	May 8, 2014	02.54.47
989 002 0007 30687	22.8	April 25, 2014	May 10, 2014	04.43.41
989 002 0008 46289	17.2	April 25, 2014	May 13, 2014	08.41.00
989 002 0007 43689	25.4	April 25, 2014	May 13, 2014	04.18.14
989 002 0008 13556	21.1	April 25, 2014	May 14, 2014	05.19.48
989 002 0007 06514	20.1	April 25, 2014	May 14, 2014	04.14.42
989 002 0008 88935	27.6	April 25, 2014	May 15, 2014	03.05.27
989 002 0007 31766	23.2	April 25, 2014	May 15, 2014	06.05.58
989 002 0008 11670	24.4	April 25, 2014	May 15, 2014	06.38.59
989 002 0007 45787	22.4	April 25, 2014	May 15, 2014	12.28.35
989 002 0008 44208	21.2	April 25, 2014	May 15, 2014	03.05.27
989 002 0007 93608	21.9	April 25, 2014	May 15, 2014	06.52.55
989 002 0008 50454	25.5	April 25, 2014	May 16, 2014	04.37.44
989 002 0008 14027	16.5	April 25, 2014	May 18, 2014	15.50.31
989 002 0008 06163	28.3	April 25, 2014	May 20, 2014	04.15.44
989 002 0008 37818	15.6	April 25, 2014	May 22, 2014	03.50.22
989 002 0008 90309	22.3	April 25, 2014	July 06, 2014	18.01.37
989 002 0008 53416	13.7	April 25, 2014	June 07, 2014	17.51.32
989 002 0008 51300	25.2	April 25, 2014	June 12, 2014	07.52.39
989 002 0008 08502	24.5	April 25, 2014	June 18, 2014	06.33.12
989 002 0008 55120	23.7	April 25, 2014	June 20, 2014	06.21.22
989 002 0008 14586	22.6	April 25, 2014	June 21, 2014	06.24.45

c) Radio telemetry

A total of 47 fish were tagged with radio transmitters in Fırnız Stream. These tagged fish were composed of 23 *Salmo opimus*, 3 *Oncorhynchus*

mykiss, and 21 *Capoeta damascina*. Total lengths of the radio-tagged fish were between 22.5 and 42.0 cm with a mean 28.4 ± 4.80 cm for *S. opimus*; the lengths were ranging from 29.0 and 33.0 cm with a mean of

30.7±2.1 cm for *O. mykiss*, and the lengths were between 26.0 and 38.3 cm with a mean of 31.2±3.3 cm for *C. damascina*. None of the radio-tagged fish achieved to pass the pool and weir type fish passage in Fırnız Stream. A total of 26 *C. damascina* were tagged with the radio transmitters in Tekir Stream. 2 of these fish died one week after being released. They were excluded during data processing (Table 3). The total lengths of 24 radio-tagged fish varied from 24.5

to 46.4 cm with a mean of 31.3±5.9 cm (Figure 4). 18 of these fishes (corresponding to 75%) successfully passed vertical slot fish passage during the 83 days of April 28th to July 20th, 2013. Six fish failed to enter the fish passage and were inhabited downstream (Table 3). Statistically, the sizes of the radio-tagged fish passed through the fish passage were shown to be no different from the fish that didn't pass ($t=0.324$, $df=22$; $p=0.749$).

Table 3. Radio-tagged *Capoeta damascina* individuals in Tekir Stream and their passing status through the vertical slot fish passage.

Frequencies of the tag	Code of the tag	Total length (cm)	Tagging date	Passing period
149.420	11	38.3	April 04, 2013	Dead
149.420	12	29.0	April 04, 2013	Dead
150.300	115	31.3	April 16, 2013	May 06 - May 15
150.320	116	36.6	April 16, 2013	June 03 - June 07
149.480	48	44.8	April 23, 2013	May 15 - May 23
149.480	46	30.0	April 23, 2013	April 23 - April 28
150.300	84	26.7	April 23, 2013	June 15 - June 23
149.480	45	26.0	May 01, 2013	June 23 - July 08
149.480	49	24.5	May 01, 2013	Did not pass
150.300	83	25.5	May 01, 2013	May 01 - May 06
150.300	80	25.8	May 01, 2013	May 23 - June 03
150.300	81	25.2	May 01, 2013	Did not pass
150.300	111	28.9	May 01, 2013	May 06 - May 15
150.300	110	46.4	May 06, 2013	May 06 - May 15
149.420	14	35.9	May 06, 2013	May 06 - May 15
149.420	13	35.5	May 06, 2013	May 15 - May 23
149.480	60	27.0	June 03, 2013	June 07 - June 15
149.480	62	29.7	June 03, 2013	June 07 - June 15
149.480	63	28.4	June 03, 2013	June 07 - June 15
150.300	88	37.5	June 07, 2013	Did not pass
149.480	68	34.6	June 07, 2013	Did not pass
148.480	65	32.7	June 07, 2013	Did not pass
149.480	61	31.4	June 07, 2013	June 23 - July 08
150.300	103	30.0	June 07, 2013	June 15 - June 23
150.300	104	29.0	June 07, 2013	Did not pass
150.300	101	27.0	June 07, 2013	July 08 - July 20

Passage efficiencies of the vertical slot fish passage were found as 26.2%, 15.4% and 75.0% for T-Bar anchor tagged fish, PIT-tagged fish, and radio-tagged fish, respectively; and statistically, it was shown to vary depending on method adopted with application method ($X^2=40.290$, $df=2$, $p=0.000$). However, the dependence on the adopted method was found to be statistically insignificant with parameters of $X^2=5.824$, $df=2$, $p=0.054$ for tagged fish with more than 20 cm in length.

No fish was detected in the trap and also no tagged fish passed through pool and weir fish passage in Fırnız Stream. Therefore it was classified as non-functional. This was explained by the fact that no fish could reach to the fish passage because of obstructions of water intake structure of trout farms, and because of insufficient ecological flow rate.

Discussion

In Fırnız Stream, no fish was detected in the trap installed into the pool and weir type fish passage. Further, no tagged fish passed through this fish passage. Therefore, it is suggested that the pool and weir fish passage in Fırnız Stream was not functional. The most important causes of this failure are i) the insufficient environmental flow rate rather than the structural characteristics of the fish passage and ii) other obstructions in Fırnız Stream. Three water intake structures of the trout farms that are present in Fırnız Stream at the downstream of fish passage obstructed fish movements to the fish passage. It was also determined that insufficient water was supplied from the fish passage. Therefore, the ineffectiveness of the fish passage in Fırnız Stream is related to attraction efficiency rather than passage efficiency.

Only brown trout (*Salmo opimus*) inhabits at the stream where the fish passage is located and other cyprinids such as *Capoeta damascina* and *Alburnus adanensis* were not present in this area because of the low water temperature (8-10 °C).

The most important impacts of the construction of reservoirs are on the ichthyofauna, especially on migratory fish, by intercepting their migratory routes, altering the hydrological regime, and reducing spawning and nursery habitats (Wagner et al. 2012; Agostinho et al. 2004). Fish passages in Turkey have been constructed without the necessary scientific knowledge on the fish. Because, although more than 370 fish species inhabit Turkish inland waters (Kuru et al. 2014), Turkey has unfortunately not an inventory for migratory fish species. Besides, there is also a literature gap about the habitat usages and hydrological requirements of inland water fish in Turkey. Whereas, an effective fish passage design requires extensive integration of biological and hydraulic data in addition to other physical data (Castro-Santos et al. 2009).

The concept of the fish passage efficiency is related to both qualitative and also quantitative evaluations. The efficiency of fish passage is considered as a qualitative concept, which involves checking whether the system provides satisfactory passage for the target species, under the environmental conditions observed during the migratory period (Makrakis et al. 2011; Wagner et al. 2012). Quantitative assessments of efficiency take into account the percentage of fish present in one side of the passage that is can move through the fish passage (Larinier et al. 2002; Castro-Santos et al. 2009; Wagner et al. 2012). Fish passage efficiency is defined as attraction efficiency and passage efficiency (Calles and Greenberg 2005; Aarestrup et al. 2003; Larinier 2008). Attraction efficiency is the ratio between the number of individuals that were detected at each fishway entrance and the number that are released downstream. The passage efficiency is the ratio of successful to overall attempts to use a fishway (Bunt et al. 1999). The attraction of a fish passage depends on its location about the obstruction, particularly the location of its entrance and the hydraulic conditions near these entrances (Larinier 2008). In the present study, no fish was detected in the trap installed into the pool and weir fish passage in Firnız Stream. Also, no tagged fish also passed through the fish passage. Therefore, it is suggested that the pool and weir fish passage in Firnız Stream has not functionality. The most important cause of this failure is the insufficient environmental flow rate rather than the structural characteristics of the fish passage and because of other obstructions in Firnız Stream. Because of three water intake structures of the trout farms present in Firnız Stream at the

downstream of fish passage and these obstructed fish movements to the fish passage. It also determined that insufficient water was supplied from the fish passage. Therefore, the ineffectiveness of the fish passage in Firnız Stream is related to attraction efficiency rather than passage efficiency. Only brown trout (*S. opimus*) inhabits at the stream where the fish passage is located and other cyprinids such as *C. damascina* and *A. adanensis* were not present in this area because of the low water temperature (8-10 °C). The efficiency of the vertical slot fish passage varied according to the methods applied (26.2% in T&Bar anchor tagged fish, 15.4% in PIT-tagged fish and 75.0% in radio-tagged fish). However, this difference was due to the size of the tagged fish. Because, when taking into account tagged fish with more than 20 cm in length, this difference among the applications was found insignificant and it was 47.5% for T&Bar anchor tagged fish, 63.3% for PIT-tagged fish and 75.0% for radio-tagged fish.

Different conclusions related to the efficiency of the fish passage have been reported in the literature. According to Agostinho et al (2002), citing to previous studies, from the 13 fish passages built on the dams lower than 16 m in South America, 10 fish passages had a functionality while 3 fish passages had not an efficiency. The height of the fish passages that have functionality varied from 5 to 16 m, while the height of ineffective fish passages varied from 2 to 10.5 m (Agostinho et al. 2002). Strong swimming fish species were passed through the vertical slot fish passages at the power plants of Emsfor and Karlshammer in River Eman in Sweden (Clay 1995). The passage efficiency of the fish ways at Finsjo in River Eman was high for upstream migrating anadromous brown trout, with 89–100% success for ascending individuals (Calles and Greenberg 2005). Fish passage efficiency was reported as 55% for sea trout in a nature-like bypass channel in a small Danish stream (Aarestrup et al. 2003) and 88.5% in a fish passage (310 m in length and 15 m in height) at the Pitlochry Dam in Scotland (Gowans et al. 1999). In a pool and weir type fish passage that is 520 m in length and 20 m in height with an angle of 45°, in Parana River, Brazil, the proportions finding and entering the fish way differed between species, ranged from 7.4 % (*Prochilodus lineatus*) to 55.4% (*Piaractus mesopotamicus*). Also, the proportion ratio of passing was different between species, ranged from 31% (*Rhinelepis aspera*) to 100% (*Prochilodus lineatus*) (Wagner et al. 2012). Passage efficiency in Lock and dam 1 fish passage that is 3.3 m in height in Cape Fear River was reported between 18 and 61% (Moser et al. 2000). The efficiency of four fish passages located at small scale hydro plants on the Gave de Pau in the South-West of France was reported as 35.3% (Baigts), 74% (Sapso), 93.8%

(Artix) and 100% (Biron) (Larinier 2008). Makrakis et al. (2011) reported that in the fish passage system known as Canal da Piracema, in Itaipu Hydroelectric Power Plant, with 10 km of extension and 120 m in height, only 0.5% of the migratory fish were able to reach the upstream sections of the channel. Attraction efficiency in a brush-type fish passage in Turkey was 22% for all fish species (Kucukali et al. 2019). Passage efficiency in this brush-type fish passage was 67.07% for all fish species (55 individuals from 82 tagged fish passed the brush-type fish passage) (Kucukali et al. 2019).

As can be seen in these studies, the species studied exhibited different rates of passage and failure, both among species and between release sites and our results are actually consistency with some of them. The low efficiencies were largely caused by the fishway design, fish behaviors, swimming performance of the species and other physical habitat factors. The swimming performance of the long-distance migratory species may reflect the differences in the ascension efficiency verified among species (Wagner et al. 2012). The behavior at fishway and swimming capacity of Turkish migratory fish species are unknown, and they should be conducted on as much as possible to support studies on fish passages.

In the present study, male *C. damascina* individuals passed through the fish passage earlier than females while towards the end of migration females became dominant. Male American shads do initiate spawning migrations earlier in the season and are smaller than females (Moser et al. 2000; Davis 1980). *Capoeta damascina* individuals passed the fish passage at night or early morning. This was corroborated by many studies for fish. The majority of the sockeye salmon passed the Seton Dam fishway during the night hours, however, pink salmon passed during the day (Pon et al. 2006).

Consequently, *C. damascina* and *A. adanensis* that are the most common fish species in River Ceyhan easily used vertical slot fish passage, however, no fish passed through the pool and weir type fish passage. To be able to design more effective fish passages, migratory species, and their habitat usages and swimming performances should be determined in Turkey.

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