Using the back calculation to study of the age and growth of Caspian trout (*Salmo Caspius*)

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Abstract

The aim of present work was to study on the growth and age structure in Caspian trout *Salmo Caspius*. Totally, 43 and 101 individuals have been captured in Cheshmehkileh River Tonekabon, Iran for back calculation and biometrical parameters study, respectively including measurement of the length, weight and age. The minimum (min) and maximum (max) ages determined 4 and 7 years while the 5 year was the most frequency group and the 6 and 7 years groups showed remarkable pattern. The mean length and weight of cathead individuals were 69.2 ± 6.2 cm and 3323 ± 677 g, respectively. Base on back calculation method in 2014, the mean length of 1, 2 and 3 years fish were 18.98 ± 3.5, 30.5 ± 7.24 and 41.7 ± 9.1 cm, respectively which all were below maturity age thus usually do not come close to the coastal waters for spawning. Moreover, males possessed larger size which might represent better growth however greater prevalence and frequency occurred in females. Growth parameters such as growth coefficient (K) and L∞ was measured 0.18, 104 cm, respectively and growth performance index (Ø') calculated 3.289 while it was an allometric negative growth. L∞ and K on the Caspian trout showed an acceptable range and proper growth. Hatchery rearing, if has very high proportion, can results to a reduction in the fitness of hatchery fish in the wild thus more empirical studies are needed to reveal the controversy of whether hatchery stocking is useful or harmful.

Keywords: Back calculation, Caspian trout (*Salmo caspius*), Caspian Sea, Growth, Age

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Introduction

The Caspian brown trout *Salmo caspius* (Kessler, 1877), an anadromous forms of brown trout that inhabits the western and southern part of the Caspian Sea which migrates mainly to the rivers during early autumn for spawning after smoltification followed by migration to the Caspian Sea. It has been listed as an endangered species according to the International Union for Conservation of Nature (IUCN) (Kiabi *et al*., 1999; Jalali and Mojazi Amiri, 2009). *Salmo caspius* is a native species of the Caspian Sea with high commercial value providing the most precious fish flesh in sea food markets (Sayyad Borani *et al*., 2007). Dramatic declines in the native populations of endangered Caspian trout has occurred over recent two decades due to various reasons including water pollution, gravel mining, construction of dams and overfishing in the rivers as Cheshmehkileh Tonekabon which reach to the Caspian Sea (Jalali and Mojazi Amiri, 2009) as seen in other freshwater species at greater risk than their terrestrial counterparts (IUCN, 2020).

The annual landings in the Caspian Sea showed a considerable decline from 16.5_{MT} in 1947 to 3.7_{MT} in 2013 during fishing season. Although catch figures related to Caspian trout were missing at some years, the periodic fluctuation average of fish landing per year recorded 2300±380 KG for 2004-2011 (Pasha Zanousi *et al*., 2013). According the recorded data a periodic fluctuation has detected in the amount of catch fish over the past decades. Earlier reports represented high catch levels of Caspian trout coming from rivers (e.g., prior to fisheries nationalization in 1942) (Karimpour and Hosseinpour, 1988). At that time, there was also a trout egg canned production mainly exported to the Russian sea food market. Another product was gutted fish with elongated abdominal cutting, treated by salt and kept in ice to avoid degradation due to tissue high fatty content of flesh fish (Abdolmalki, 2013).

The mean body length/weight (I.e., commercial size) of caught Caspian trout in recent years showed a descending remarkable trend from 5 kg in 1946 to 2.5 kg in 2001 (Ghaninejad *et al*., 2002). Pasha Zanousi *et al*., (2013) also reported an average body weight of 2.5 kg for Caspian trout. *Iranian Fisheries Organization* for restocking of natural population and increase the potential of fishery return rate of this species release several thousand of hatchery rearing Caspian trout fingerlings every years. During 1983-2003, 10.8 million pieces of young individuals released that 97.3 $_{MT}$ of them was landed. Estimating 40% of illegal or unreported catch as well as the fishing of broodstocks for artificial reproduction, the approximate of overall catch calculated around 136.2 $_{MT.}$ Considering an average weight of 2.5 kg for individual, the total number of caught fish would be 54488 pieces which result to anticipate a fishery return rate of 0.5% in associated to the number of released fish (Abdolmalki, 2013). However, despite a fairly moderate fishing operation, increasing the number of releasing fish to maintain the ecological balance, secure biodiversity and prevent total extinction of the species should be considered imperatively. Importantly, it should be keep in mind that the long-term hatchery stocking and captive breeding can lead to the reduction in the fitness of hatchery fish in the wild recipient population (Kitada, 2020).

Analyzing of Fish ages relies on the presence on calcified structures (CSs) with a structural pattern of growth rings in terms of a translucent zones and succession of opaque, as well as on knowledge of the periodicity of that growth pattern and deposition (Carbonara *and Follesa,* 2019). There are several CSs in fish that can be used for ageing analysis including: scales, otoliths (sagittae, lapilli, asterisci), vertebrae, spines and opercular bones (Panfili *et al*., 2002). Understanding of the stock structure is a key component for choosing the proper strategies in fisheries conservation and management, due to the establishment of the basic work units in which the fishery can be evaluated and managed (Tanner *et al.*, 2015). Making the best management decisions is happing base of the knowledge which sufficient to infer cause-and-effect relationships between a fish population and management actions (e.g., harvest regulations) (Radomski and Goeman, 1996). Obtaining of a complete knowledge is impossible or rare or thus the managers should attempt to acquire as much information as resources allow regarding a fish population (Pope *et al*., 2010).

The back calculation used to reconstruct growth patterns from hard parts of fish (scales, otoliths and bones) (Lea, 1910). The approach involves of using measurements base on bony structures to derive, or back-calculate, body length at ages prior to capture. Almost a century the generate individual growth histories of fishes achieved by using back-calculation (Francis, 1990) and has proved to be a valuable tool for fish ecologists and fisheries scientists. The back-calculation model can estimate fish size across previous ages based on otoliths represents as an alternative to model growth (Vigliola and Meekan, 2009).

Back calculation information in Caspian trout caught broodstocks was scare. Moreover, growth condition of the species particularly during prematurity period in their natural habitat, population structure and actual size when the fish is young should be more clarified which might provide some insights into the Caspian trout growth requirement in natural ecosystem, growth coefficient, fish age composition and length. To the best of our knowledge this is the first study focusing on Caspian trout wherein length/weight relationship along with length estimation for different age groups are identified through back calculation method.

Methodology

This study was done during 2013-2015. The annual fishing season for bony fish starts on October 10th and terminates in early April in the south coastline of the Caspian Sea. The fish sampling site distributed along the shore where beach seine fishing cooperatives operating in the western part of Mazandaran province, the local fish markets in Tonekabon as well as 'a single breeding and cultivation center (Kelardasht, Mazandaran). The reproduction migrations of Caspian trout broodstocks occurs in Iranian rivers in the late December every year. The spring population of the Caspian trout is also thinly caught during March-April. The sampling and biometric analysis of fish landed in commercial beach seine operations were carried out at the outset of fishing season in Tonekabon.

Due to limited number of rare species among the catch composition, a similar number of scales were prepared for age detection purpose. The number of 50 individuals trout used to biometric study in order to specify the primary parameters such as body length/weight, length composition, and age groups. The related fishing data for the Caspian trout were obtained from the' *Fishing affairs Department of Iranian Fisheries Organization.* A biometric board with a 1 mm calibration precision and digital balance with 1 g weighing precision were used for measuring fork length and scales weight, respectively.

To identify fish age a few scales were singled out from the backside of pectoral fins and the area above the lateral line, using count method for the yearly growth lines within the scales (Thomson, 1997). A completely random procedure was used in the sampling of fish scales (Martinson *et al*., 2000). About 3-5 scales were selected from the area between the dorsal fin and the lateral lines. Back calculation was utilized for identification of hard structure in the sampled fish. The method involved estimation of fish size at different ages and investigating the presence of any reasonable relationship between the fish length increase and the rise in hard body structure.

In addition, a micrometer equipped with micro projector or calibrated optic lenses on microscope and loops were applied to measure the width and breadth of rings. Meanwhile, by using a linear relation between the length increase rate and the rays in the examined structure and by using the Fraser-lee formula, the length growth rate in earlier years were calculated (Parafkandeh, 2008).

Back-calculations were based upon a linear regression model developed by Fraser (1916) and Lee (1920), which assumes that fish length is directly proportional to scale radius (Dahl, 1909). The model can be written as:

$$Li = C + (LT - C)*(Si / ST)$$

Where *I, is* age at the time of annulus formation; c, islength of fish at the onset of scale formation; *LT, is* fish length at capture, *Li, is* fish length at time of annulus formation; *ST, is* scale radius at capture; *Si, is* scale radius at time of annulus formation

Scale radii at time of annulus formation (*Si*) were as follows: first annulus or ocean age-l (S I=*Sa*), second annulus or ocean age=2 (*S2=Sa+Sb*), third annulus or ocean age=3 (*S3*=*Sa*+*Sb*+*Sc*), and fourth annulus or ocean age=4 (*S4*=*Sa*+*Sb*+*Sc*+*S*) (Figs. 1 and 2). In estimating length of fish at time of scale formation (*c*), we used length measurements taken from fry before they developed scale circuli. Helle (1979) reported that chum salmon fry (*n*=29) in the intertidal zone at Olsen Creek, Prince William Sound, had scales but no circuli. On average, these fish were 46 mm from the tip of the snout to the fork of the tail (TSFT).

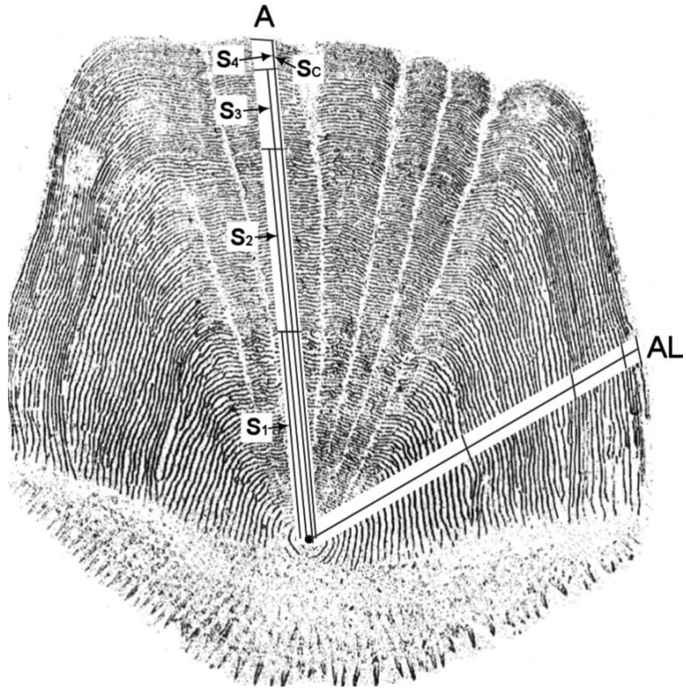

Figure 1: Scale of an ocean-age.3 Caspian trout illustrating the INPFC method and Traditional method (anterior-posterior reference line). With years of growth (Martinson *et al*., 2000).

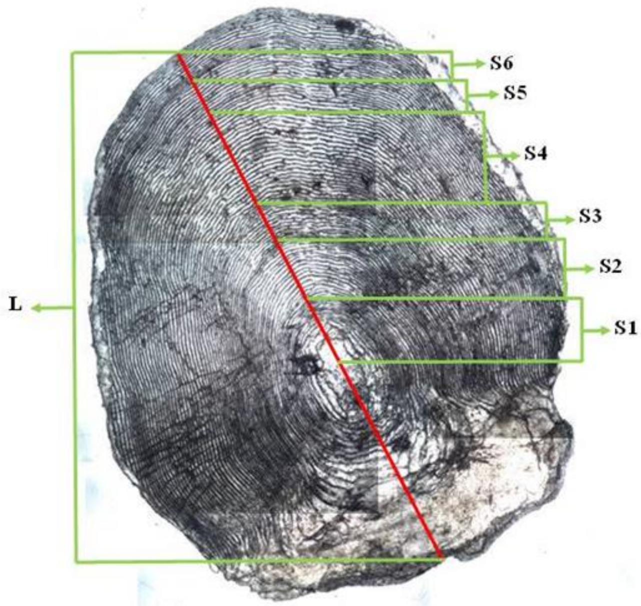

Figure 2: Scale of Caspian trout illustrating the INPFC method and Traditional method (anterior-posterior reference line). With years of growth (Martinson *et al.*, 2000).

Following a careful recording of these basic data, certain growth parameters, such as length frequency, weight frequency, age composition, weight/length relationship and their effects on stock preservation were examined.

Growth performance index (Ø')

The overall growth performance index was calculated empirically (Munro and Pauly, 1983) using the formula Phi prime:

$$(\mathbf{Ø'}) = \log 10\ K + 2{*}\log 10\ L\infty$$

Where, K is expressed on annual basis and L∞ in cm.

The relation of weight to length was calculated applying the exponential regression as the following equation:

$$W = a \times L^{b}$$

Where *W* is the total weight (g) and *L*, the fork length (mm), and *a* and *b* are parameters to be estimated (Ricker, 1975). The condition factor (CF) was calculated as the following equation (Jami *et al*., 2019):

$$CF = W/L^{b} \times 100$$

Where *W* is the total weight (g).

The Bertalanffy growth curve (1938) was fitted to the observed length at age data for the resulting age-length key using a nonlinear. Estimation method the following:

$$Lt = L\infty\ (1 - e^{-K\ (t-t0)})$$

Where Lt is the length at age t, L∞ is the theoretical max length, K is a growth coefficient and t0 is the hypothetical age for Lt =0.

Length at age was estimated from the plots of SLCA, PROJMAT and ELEFAN 1, and the empirical method of Froese and Binohlan (2000).

Survival rate (*S*) was calculated using the catch and juvenile releasing to estimate terminal fishing mortalities.

The instantaneous coefficient of total mortality (*Z*) was transformed from the survival rate as: $Z = -\ln S$.

The instantaneous coefficient of natural mortality (*M*) was estimated using the ZM model (Zhang and Megrey, 2006) with Von Bertalanffy (1938) growth parameters and a max age (*t*max) (Caspian Sea Biodiversity, 2006). The equation of ZM model is:

$$M = \check{\beta} k / e^{k\ (tmb - t0)} - 1$$

Where β the power parameter of the length–weight relationship, *t*0 is the hypothetical age for *Lt* = 0, and *t*mb is the critical age, which can be estimated as *t*mb = 0.440*t*max (Zhang and Megrey, 2006). The instantaneous coefficient of fishing mortality (*F*) was calculated as:

$$F = Z - M$$

After recording the data, we have attempted to determine the mean differences using ANOVA and homogeneous and heterogeneous groups were separated based on parametric and nonparametric (Mann-Whitney test) statistical tests.

Results

Based on the obtained results from the samplings in 2014-15, (local market in Tonekabon), mean body length, weight and age of male Caspian trout were measured 75.4±37.8 cm ¸3771±3147 g and 5.4±.9 yr (n=7) respectively, whereas the values for female ones were 68±5.9$_{cm}$, 3236±696.6$_{gr}$ and 6.4± 0.97 yr (n=36), respectively. The male Caspian trout possess bigger size and older than females ones (Table 2). The female fish were dominant in terms of sexual ratio (83.7%) while males accounted for the remaining 16.3% of the examined fish population.

The data related to the females did not reflected a normal distribution pattern and could not be normalized by traditional procedure, thus making it necessary to use the nonparametric Mann-Whitney test which showed a significant difference in length/weight relationship between male and female of Caspian trout (Figs. 5 and 6).

The results of back calculation studies in 2014 including mean length at various age groups are presented in Table 1 which show the mean fork length of 1, 2 and 3 years fish were 18.98±3.5, 30.5±7.24 and 41.7±9.1 cm, respectively.

Table 1: Mean fork length of the Caspian trout at different ages groups based on Back calculation in 2014.

Age	1+	2+	3+	4+	5+	6+	7+
Mean ± S.D.	18.98±3.5a	30.5±7.24b	41.7±9.1c	53.9±10.96d	63.7±9.7e	68.8±8.2ef	74±9.9f

According to Duncan test, mean length between the ages of 1 to 5 years (according to background processing) showed significant difference ($p \leq 0.05$) while it was not significant between the groups of 5, 6 and 6, 7 years.

In addition, since the age groups of mentioned fish, were below the maturity age, they did not approach coastal waters during spawning season and were absent in the catch composition. Mean length of 4, 5, 6 and 7 years of Caspian trout were measured 53.9, 63.7, 68.6 and 74 cm. Duncan's Test results presented in Table 2 (via back calculation) showed a significant difference ($p \leq 0.5$) whereas the values pertaining to age groups 5, 6, and 7 fail to show any significant difference.

Based on the results in Table 2, mean length, weight and age of female Caspian trout were 68±5.9 cm, 3236±969.6 g and 6.4±0.9 yr, respectively. However, the figures related to male of Caspian trout included 75.4±37.8 cm, 3771.4±314.7 g and 6.4±0.9 yr reflecting the male's being bigger in size compared to female Caspian trout.

Table 2: Mean length, weight and age of Caspian trout differentiated by sex using back calculation method in 2014.

	Weight(gr)	Length(cm)	Age(years)	Number
Female	3236± 696.6	68± 5.9	5.4 ± 0.9	36
Male	3771.4± 314.7	75.4 ± 3.8	6.4 ± 0.97	7
Mean	3323.3± 677	69.2 ± 6.2	5.6± 0.97	43

As illustrated in Table 3, the age of Caspian trout range 0-7 years and age groups 4, 5, 6 and 7 consist 9.5%, 40.5%, 26.2% and 23.8%, respectively. The minimum (min) and maximum (max) ages determined 4 and 7 years (mean=5.6) while the 5 year was the most frequency group and the 6 and 7 years groups showed remarkable pattern. The mean length and weight of cathead Caspian trout were 69.2±6.2 cm (min 57 and max 81 cm) and 3323±677 g (2400 to 5600 g), respectively in catch composition (Table 3).

Table 3: The age composition, mean length and weight of Caspian trout from commercial fisheries in the south of the Caspian Sea (Mazandaran province) in 2014.

Age groups (years)	4	5	6	7	Mean
Number	4	17	11	10	42*
Length(cm)	61.8±5.1	67.8 ±5.3	70± 5.6	74.5 ±4.5	69.2±6.2
Weight (gr)	2720±571	3141±547	3345±541	3910±699	3323±677
Abundance (%)	9.5	40.5	26.2	23.8	100*
Min and Max length(cm)	57-68	59-76	63-78	67-81	57-81
Min and Max weight(gr)	2500-3400	2400-4400	2400-4400	3300-5600	2400-5600

*Total

Growth performance index (Ø'), growth rate (K) and L∞ were calculated, 3.373, 0.38 and 78.8, respectively. Natural mortality was determined around 0.44, which showed a significant trend of mortality (Table 4) (Fig. 3).

Table 4: Calculation of growth rates, natural mortality coefficient of Caspian trout in 2014.

´ø	Natural mortality coefficient	L∞	(K)
3.373	0.44	78.8	0.38

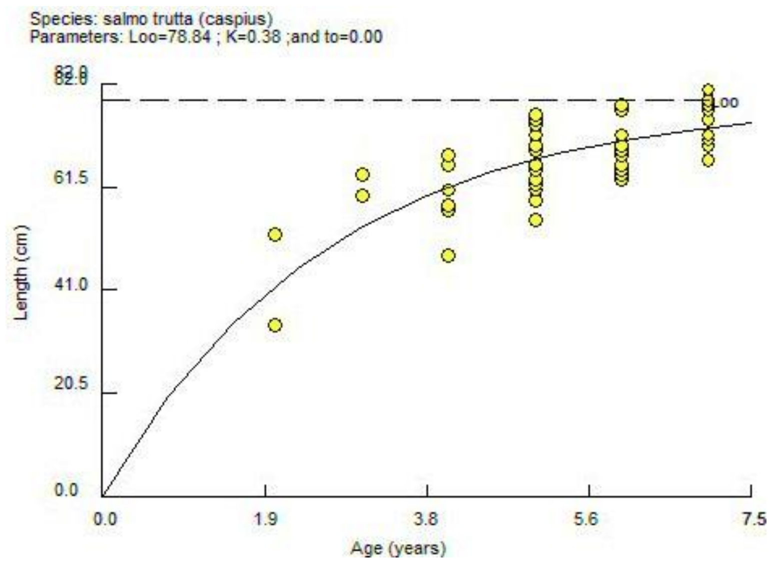

Figure 3: Von Bertalanffy growth curve of the Caspian trout related to biometric data in 2014.

Von Bertalanffy growth equations were estimated as:

$L_t = 78.84(1 - e^{-0.38\,(t-0)})$

Where, M= 0.44, Z=0.7, F=0.26

The length-weight relationship of Caspian trout is $W=0.89L^{2.49}$, R2=0.74.

The calculated growth patterns based on t-test showed allometric negative growth (n=101) (Fig. 4 to 6). The amount of b associated to the length and weight was 2.49 which implied an allometric negative growth (Table 5).

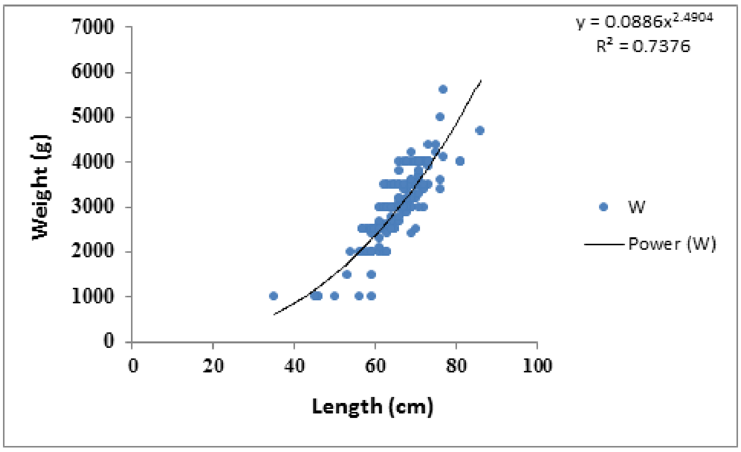

Figure 4: Length-weight relationship of Caspian trout (total of female and male) in the south of the Caspian Sea (Mazandaran Province) in 2014.

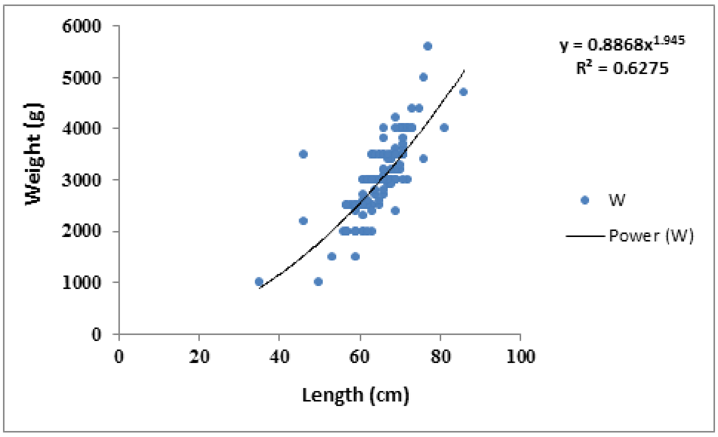

Figure 5: Length-weight relationship of female Caspian trout in the south of the Caspian Sea (Mazandaran Province) in 2014.

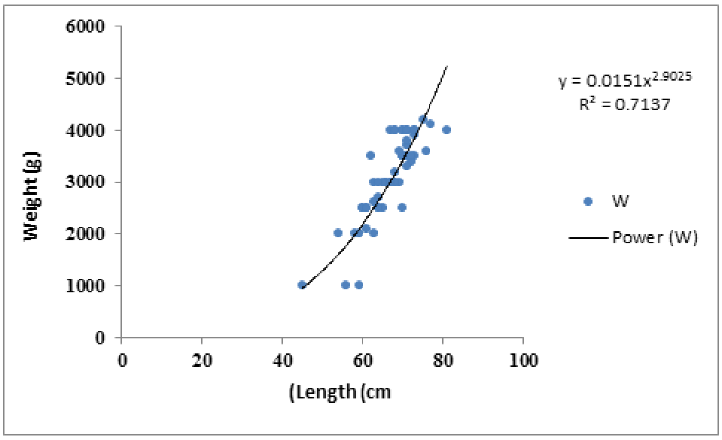

Figure 6: Length-weight relationship of male Caspian trout in the south of the Caspian Sea (Mazandaran Province) in 2014.

Table 5: CF of Caspian trout in 2011-2012, 2014 and Back calculation (2014-2015).

Year	Mean weight(g)			Mean length(cm)			CF
	Min - Max	Mean±SD	Number	Min - Max	Mean±SD	Number	
2011-2012	2100- 4200	3245.5±622	101	60-76	67.5±50	101	1.05
2014-2015	1000-4100	2865±83.70	98	45-81	63.5±6.98	98	1.11
Back calculation (2014-2015)	2400-5600	3323±677.10	43	57-81	69.2±6.20	43	1.00

The CF of Caspian trout declined from1.05 in 2011-2012 to 1 in 2014, but it increased in 2014-2015 (related to actual biometrical data).

The Table 6 representing Von Bertalanffy (1938) growth parameters and Phi prime of brown trout in different locations. Base of used actual data in present study growth performance index (Ø') was 3.3 L∞, which was comparable with other studies.

Table 6: Von Bertalanffy growth parameters and Phi prime of brown trout in different location.

Study area	L∞ (cm)	K (year $^{-1}$)	´ø	Author
Afon Dyfi, UK	21.6	0.34	2.2	Crisp and Beaumont, 1995
River Ucero	65.94	0.18	2.89	Lobon-Cervia *et al*., 1986
River Avion Millanos, Spain	64.04	0.18	2.87	Lobon-Cervia *et al*., 1986
Aksu stream, Turkey	32.13	0.12	2.09	Arslan *et al*, 2007
South of the Caspian Sea	78.8	0.38	3.373	Present study (the actual data)
South of the Caspian Sea	104	0.18	3.289	Present study (Data based on Back calculation)

Based on back calculation (2014), mean length during 1st, 2nd and 3rd years provided the following means 18.98±35, 30.5±7.24, and 41.7±2.1 cm, respectively (Table 7).

Table 7: Mean length of all ages on brown trout in different places.

Study area	0	1	2	3	4	5	6	7	8	9	Author
Loch lanish	8.7	21.2	36.1	43.1	50.2	57.1	63				Campbell, 1971
LCarn a chuillin	4.5	13	25.8	34.4	40	44					Campbell, 1971
Loch Rannoch	5.7	12.6	19.8	24.8	28.8	31.8	37.8	46	58.8	62.1	Campbell, 1971
Loch Einich	3.6	9.2	14.6	18.7	20.9	24.2	28	31	36.5		Campbell, 1971
South of the Caspian Se		18.98	30.5	41.7	53.9	63.7	68.6	74			Present study

Discussion

The results of present study suggested fish age range of 4-7 years' migration after autumn downpour when water temperature of rivers descending below 18 ^{0}C (reference regarding the water temperature). Considering the time span in which fall run Caspian trout begins at the end of summer to the middle of fall with rather mature gonads ready for spawning (Shirangi *et al.*, 2011), it may well explain the reason why premature Caspian trout were not observed among the samples. The analyzing of the data from samples during 2014-2015 indicated the bigger size of males rather than female ones while, the CF during 2011-2012 showed higher value.

A decrease in length and weight of Caspian trout has been observed from 4.8 kg in 1946 to 3.5 kg in 1973 and continued decline in 1986 and to the 2.63 kg in present study. Similarly, a descending remarkable trend from 5 kg in 1946 to 2.5 kg in 2001 has reported by Ghaninejad *et al*. (2002). During the years mentioned above, the weight variation range was 1.8-12.7 (1946), 1.8-6.6 (1973) and 0.75-5.2 kg (1986), respectively. (Faridpak, 1947; Karimpour, M. and Hoseinpour, 1988). Apart from declined weight, the Caspian trout has also gradually experienced descending trend in average length during the past years. In 1947, mean length of Caspian trout recorded was 83 cm whereas in 1973 it reached 67 cm, 63 cm reported in 1983 and further decreased to 59.8 cm in 2007. However, it shows a slightly promising increase in 2014 by 69 cm. In the present study the range of the length measured 57-81 cm. There are variations among Caspian trout ids regarding the length at maturity, primary age at sexual maturity, fecundity, egg size, temperature requirements during spawning and incubation which are affected by genetic trait of species and their habitat condition (Pasha Zanousi *et al*., 2013). The mean weight of caught Caspian trout in 1947, 1973 and 1984 were measured 4865, 3948 and 2627 g, and 780, 670 and 630 mm, respectively for the length (Naderi and Abdoli, 2004). The age groups of Caspian trout landed in 1973 were 4.5 and 6 years with the mean body length of 48.63 and 77 cm, respectively (Faridpak, 1947; Karimpour, M. and Hoseinpour, 1988). The observed decline in length and weight might be associated to growth of fishing pressure on fishery stocks that has gone beyond sustainability boundary (Abdolmalaki, 2013). Declines in Pacific salmon size, primarily resulting from shifting age structure, are associated with climate change could cause increasing metabolic and developmental rates and competition at sea for food has reported in based on 60 years of measurements from 12.5 million fish across Alaska (Oke *et al.,* 2020).

The CF of the caught Caspian trout spawner during 2011-2012 and 2014-2015 ranged from 1 to 1.1, respectively. The calculated CF of Caspian trout from Guilan province shores was 0.95±0.105 ranging from of 1.28-0.79 (Abdolmalaki, 2013). Growth qualities, mortality rate, and the gender and age of brown trout were also investigated by Arsalan *et al*. (2007) revealing male, female population composition at 52.1% and 47.9% with their age ranging from 1 to 7 years. The calculated length-weight relationship was $w=0.015\ L^{2.9}$.

The various sex composition in caught Caspian trout spawner from the Cheshmehkileh Tonekabon River was observed in different years. The sex composition were 33% (male) and 65% (female) in 1983, 45% (male) and 55% (female) in 2006 while the present study showed 27.7% and 72.3% for the male and female, respectively. Such variations in sex composition might be attributed to ecological changes or artificial propagation program (Pasha Zanousi *et al*., 2013).

The peak migrations to rivers occurring after autumn downpour when water temperature of rivers descending below 18 ^{0}C due to heavy downpour periods or torrential rains in November. According our results 5 year was the most frequency group which tend to migration in shorelines and entering the rivers for natural reproduction. Although caught of a 38 years old brown trout is reported in the Norwegian waters (Svalastong, 1991), the max size and age of a fish are determined by various factors such as genetic properties, consumed food, water quality, water temperature and fishing efforts (Crisp, 2000).

The back calculation results showed difference size and weight between male/female of Caspian trout while male fish possessed larger size which might represent better growth however the greater prevalence and frequency occurred in female. Moreover, based on back calculation of Caspian trout (2014), mean length of 1, 2 and 3 years individuals all were below maturity age thus do not usually come close to the coastal waters for spawning. The latter may explain the absent of them in the catch composition. Growth index (Ø') 3.3 in Caspian trout was comparable to brown trout from other regions which might be related to genetic trait, the brakishwater of Caspian Sea, nutrition and the environmental conditions (Pasha Zanousi *et al*, 2013). The observed natural mortality might be contributed to predators and pollution. However, more convenience data from assay and experimental studies will be required to be more clarified.

The calculated growth rate and L∞ were 0.38 (close to the max length) and 78.8, respectively which is in acceptable level showing the suitable growth function. Nevertheless its growth rate particularly during prematurity phase in fresh water seems rather poor. (Sayyad Borani *et al*., 2015). These parameters may vary for different sexes under different condition which might be attributed to their species specific qualities, and sex while ripening.

Determining fish age composition usually forms an important objective of any stock assessment program and consider as a vital issue on successful fish reproduction program as well. In the latter spawner usually tend to yield high quality gametes at certain age (Pasha Zanousi *et al*, 2013). In order to determine the effects of fecundity potentials of female Caspian trout on effective factors in artificial fertilization, three groups of spawners in the ages 4, 5 and 6 years used for fertilization with male sperms. The results showed 4 years spawners have the greatest mean length (59 cm), mean weight (2150 g), the highest egg diameter, absolute fecundity, the highest fertilization percentage, survivability rate accounted for the greatest relative fecundity and the most efficient sperm yield (Rahbar *et al*, 2011).

Hatchery rearing, if has very high proportion, can results to a reduction in the fitness of hatchery fish in the wild, and long-term hatchery stocking might replace wild genes in the recipient population, endangering many native gene pools (Casanova *et al.*, 2022) and harm the sustainability of populations. Thus for conservation purposes short-term uses of hatchery stocking can be helpful (Kitada, 2020). Obviously, more empirical studies are thus needed to reveal the controversy of whether hatchery stocking is useful or harmful.

References

Abdolmalaki, Sh. 2013. Preparing broodstock of *Salmo trutta Caspius* from Guilan Province Rivers. Iranian Fisheries Science Research Institute. Research Report No. 47414. 36P. (In Persian).

Arslan, M., Yildirim, A., Bektafi, S. and Atasever, A., 2007. Growth and Mortality of the Brown Trout (*Salmo trutta L.*) Population from Upper Aksu Stream, Northeastern Anatolia, Turkey. *Turkish Journal of Zoology*, 31, 337-346

Campbell, R.N., 1971. The growth of brown trout *Salmo trutta L.* in northern Scottish lochs with special reference to the improvement of fisheries. *Journal of Biology*, 3, 1-28.

Carbonara, P. and Follesa, M.C. (eds), 2019. Handbook on fish age determination: a Mediterranean experience. Studies and Reviews. No. 98. Rome, FAO. 2019. 192P. Licence: CC BY-NC-SA 3.0 IGO.

Casanova, A.; Heras, S.; Abras, A.; Roldán, M.I.; Bouza, C.; Vera, M.; García-Marín, J.L.; Martínez, P. 2022. Genomic Hatchery Introgression in Brown Trout (*Salmo trutta* L.): Development of a Diagnostic SNP Panel for Monitoring the Impacted Mediterranean Rivers. Gene, 13, 255. https://doi.org/10.3390/genes13020255

Caspian Sea Biodiversity Database (cited March, 2006). Available from URL: http://www.caspianenvironment.org/

Crisp, D.T. and Beaumont, W.R.C., 1995. Trout (*Salmo trutta*) population of the Afon Cwm, a small tributary of the Afon Dyfi, Mid-

Wales. *Journal of Fish Biology*, 46, 703-716.

Crisp, D.T., 2000. Trout and Caspian trout Ecology, Conservation and Rehabilitation, Blackwell Science, Oxford.

Francis, R.I.C.C., 1990. Back-calculation of fish length: a critical review. J Fish Biol 36:883–902

Faridpak F. 1947. Fecundity Capacity of Salmo trutta Caspius. Center of Science and Technology of Ichthyology, Fisheries Company in Iran, Anzali. 16 P. (In Persian).

Fraser, C.McL., 1916. Growth of the spring Caspian trout. Trans. 2nd meets. (1915). *Partners' Advisory Council Fisheries Society*, 29-35.

Froese, R. and Binohlan, C., 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at max yield per recruit in fishes with a simple method to evaluate length frequency data. *Journal of Fish Biology*, 56, 758-772**.**

Ghaninejad, D., Moghim, M., Abdolmalaki, Sh. and Sayyadbourani, M., 2002. Stock assessment of bony fishes in Iranian part of the Caspian Sea. Iranian Fisheries Science Research Institute, Project Report. 98 P. (In Persian).

Helle, 1.H., 1979. Influence of marine environment on age and size at maturity, growth, and abundance of chum Caspian trout, *Oncorhynchus keta* (Walbaum), from Olsen Creek, Prince William Sound, and Alaska. Ph.D. Thesis, Oregon State University, Corvallis, Oreg.

IUCN, 2020. The IUCN Red List of Threatened Species. https://www.iucnredlist.org.

Jalali, M.A. and Mojazi Amiri, B., 2009. Threatened fishes of the world: *Salmo trutta caspius* (Kessler, 1877). *Environmental Biology of Fishes*, 86, 375-376.

Jami, M. J., Abedian Kenari, H. Paknejad, M. Mohseni., 2019. Effects of dietary b-glucan, mannan oligosaccharide, Lactobacillus plantarum and their combinations on growth performance, immunity and immune related gene expression of Caspian trout, Salmo trutta caspius (Kessler, 1877), Fish & Shellfish Immunology, 91, 202-208, https://doi.org/10.1016/j.fsi.2019.05.024

Karimpour, M. and Hoseinpour, N., 1988. Caspian Salmon (*Salmo trutta caspius*). Iranian Fisheries Science

Research Institute. 134P. (In Persian).

Kiabi, B., Abdoli, A. and Naderi, M., 1999. Status of the fish fauna in the South Caspian Basin of Iran .*Zoology in the Middle East*, 18, 57-65.

Kitada, S., 2020. Lessons from Japan marine stock enhancement and sea ranching programmes over 100 years. *Reviews in Aquaculture*, 1–26. https://doi.org/ 10.1111/raq.12418

Lea, E., 1910. On the methods used in the herring investigations. *Conseil Permanent International Pour L'exploration de la Mer*, 53,7–25

Lee, R.M., 1920. A review of the methods of age and growth determination in fishes by means of scales. Fishery Invest, Lond, SeT. 2, vol. 4 no. 2.

Lobon-Cervia, J., Montanes, C.M. and Sostoa, A., 1986. Reproductive ecology and growth of a population of brown trout (*Salmo trutta L*.) in an aquifer-fed stream of Castile (Spain). *Hydrobiology*, 135, 81-94.

Martinson E.C., Masuda M.M., Helle J.H. 2000. Back-calculated fish lengths, percentages of scale growth, and scale measurements for two scale measurement methods used in studies of salmon growth. N. Pac. Anadr. Fish Comm. Bull. **2**: pp. 331–336.

Munro, J.L. and Pauly D., 1983. A simple method for comparing the growth of fishes and invertebrates. *ICLARM Fish byte*, 1(**1**), 5-6.

Naderi M., Abdoli A. 2004. Fish Species Atlas of South Caspian Sea Basin (Iranian Waters) Abzian Publications, Tehran. 238P. (In Persian).

Oke, K. B., Cunningham, C. J., Westley, P. A. H., Baskett, M. L., Carlson, S. M., Clark, J., Hendry, A. P., Karatayev, V. A., Kendall, N. W., Kibele, J. ,Kindsvater, H. K., Kobayashi, K. M., Lewis, B., Munch, S., Reynolds, J. D., Vick, G. K., Palkovacs, E. P. Recent declines in salmon body size impact ecosystems and fisheries. Nat Commun, 11, 4155. https://doi.org/10.1038/s41467-020-17726-z

Panfili, J., de Pontual, H., Troadec, J.P. and Wright, P.J. (eds.), 2002. Manual of fish sclerochronology. Brest, France, IFREMER-IRD co-edition. 464P.

Parafkandeh F. 2008. Age determination in aquatic animals. Iranian Fisheries

Science Research Institute. 139 P. (In Persian).

Pasha Zanousi A., Dorafshan S. and Ebrahimzadeh M., 2013. Caspian trout (*Salmo trutta caspius*). Nashre Amokhteh Publication, Esfehan. 172 P. (In Persian).

Pope, K.L., Lochmann, S.E. and Young, M.K., 2010. Methods for Assessing Fish Populations. Nebraska Cooperative, Fish & Wildlife Research Unit -- Staff Publications. Paper 73. http://digitalcommons.unl.edu/ncfwrustaff/73

Radomski, P.J. and Goeman, T.J., 1996. Decision making and modeling in freshwater sport-fisheries management. *Fisheries*, 21(**12**),14–21.

Rahbar, M., Nezami, Sh., Khara, H., Rezvani, M., Khidadoust, A. and Eslami, S., 2011. Effect of age on reproductive performance in female Caspian brown trout. *Caspian Journal of Environmental Sciences*, 9, 97-103.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, 191, 1-382.

Sayyad bourani, M., Abtahi, B. and Bahmani, M., 2007. Determination of suitable size for releasing of *Salmo trutta caspius* juveniles by osmoregulation ability. Iranian Fisheries Science Research Institute, Report number: 86/1568. 56 P. (In Persian).

Sayyad Bournai, M., Abtahi, B., Bahmani, M. and Falahatkar, B., 2015. The effect of size on osmoregulation ability, chloride cells and Na^+ /K^+-ATPase activity in Salmo caspius Kessler, 1877 juveniles. *Iranian Journal of Ichthyology*, 2(**2**), 93–104

Shirangi, A., Kalbassi, M.R. and Dorafshan, S., 2011. Microsatellite Polymorphism Reveals Low Genetic Differentiation between Fall and Spring Migratory Forms of Endangered Caspian Trout, *Salmo trutta caspius* (Kessler, 1870). Caspian Journla of Environmental Sciences, 9, 1, pp. 9-16.

Svalastog, D., 1991. A note on max age of brown trout, *Salmo trutta L. Journal of Fish Biology*, 38, 967-968.

Tanner, S.E., Reis-Santos, P. and Cabral, H.N., 2015. Otolith

Chemistry in Stock Delineation: A Brief Overview, Current Challenges and Future Prospects. *Fisheries Research*, 173, 206–213.

Thomson, J.M., 1957. Interpretation of the scales of the yellow-eye mullet *Aldrichetta forsteri* (Mugilidae). Aust. J. Mar. Freshwat. Res., 8 (1): 14-28.

Vigliola, L. and Meekan, M.G., 2009. The Back-Calculation of Fish Growth From Otoliths. In: Green B.S., Mapstone B.D., Carlos G., Begg G.A. (eds) Tropical Fish Otoliths: Information for Assessment, Management and Ecology. Reviews: Methods and Technologies in Fish Biology and Fisheries, vol 11. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-5775-5_6

Von Bertalanffy, L., 1938. A quantitative theory of organic growth. *Human Biology*, 10, 181-243

Zhang, C.I. and Megrey, B.A., 2006. A revised Alverson and Carney model for estimating the instantaneous rate of natural mortality. *Transactions of the American Fisheries Society*, 135(**3**), 620–633.