Caspian Sea Level Fluctuations

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ABSTRACT

In this paper the most important factors that influence the Caspian Sea level rising and the probable and improbable factors are discussed in detail. A cyclical behavior of the level of the Caspian Sea according to local records was proposed. This cyclic fluctuation of the sea level is the long-term behavior of the sea so that the investigation is not restricted to a specific time interval. The statistical data from water table that is the function of the atmospheric and climatologic conditions was also used. It was observed that although the countries located in the northern part of the sea have more effective control over the sea level, in order to have a fixed level and to prevent surplus situations such as flood and surcharge, all of the neighboring countries should perform unidirectional efforts. In the whole, the two following points were determined:

Firstly it has been observed that this rising is instantaneous (or stochastic) rather than deterministic. Secondly the maximum sea level rising in the specific return period has been recorded.

Key words: Caspian, level, river, tectonic

INTRODUCTION

The Caspian Sea is one of the most important resources of Iran from different points of view such as economic, social and political aspects. It should be investigated by researchers and coastal experts, there is just a little information devoted to the short period statistics of internal rivers and their water sources.

With regard to the sea level rising and the probable damages in the southern regions of the sea, clear information should be gathered about hydrology, the time continuous of this rising and its maximum degree as done by a lot of researchers all over the world (e.g. Peltier and Tushingham, 1989; Van Der-Veen, 1989; Emery and Aubery, 1985). A great deal was done on the mean sea levels and level fluctuations (Kidson, 1982; Woodworth, 1987).

According to the recorded investigations, the fluctuation of the Caspian Sea level is natural but there is not complete scientifically explanation due to lack of basic information related to the sea.

Archaeology and historical studies have made it clear that water table has changed about 8 meters during 2000 years (Tooly and Ielgersma, 1998).

The basic specifications of Caspian Sea are presented in Table 1. Regarding the Sea depth, it is divided into three sections

Namely: Northern, Middle and Southern. The Sea depth is different in these sections and it increases from the north to the south. Table 2 shows the depth of different

Sections of the sea (Tehran Times, 1992), As it is shown in table 2 the average depth of the Northern section is about 6.2 meters which is low due to rivers run off like Volga, Ural and Emba. The water in a small part of this section is 25 meters deep and the depth in a large part of it is between 2 and 3 meters. A large part of this section is frozen in winter and causes fishes to migrate to the middle and southern sections.

Average depth of middle section is 175.6 meters. There is an outgrowth called underneath (or the limbo) that is located between central and southern regions. In southern section Lankran Port is the deepest part of the sea with 1020 meters depth. Ghaphghaz, Talesh and Alborz mountains are over looking this section which is located in the southern part of Caspian sea. The change in the area of the sea to the sea level is shown in Table 3.

Table 1 Basic specifications of the Caspian Sea by Ahangar (1991).

Area of the sea catchment	3723000 km^2
The Iranian catchment area	256000 km^2 (equal to 7 %)
Volume of water in 1974	75158 km^3 (-28.68 m)
Volume of water in July 1996	77000 km^3 (-27.03 m)
Circumference of sea	6379 Km
The length of coast in Iranian domain	992 Km (equal to 15.5%)
Caspian Sea Area survey	Max. 424300 km^2 (1929) Med. 393000 km^2 (1950) Min.368000 km^2 (1977)
Caspian Sea Area in July 1996	416000 km^2
Sea width	Max. 1100 km, Med. 310 km, Min. 202 km
Sea length	1204 km

Table 2 Average and Maximum depth of water in different section with area and volume

Section	Med. Depth (m)	Max. depth (m)	Area relative to The total (%)	Volume relative To the total (%)
Northern	6.2	25	27	1
Middle Section	175.6	770	37	35
Southern Section	325	980	36	64

The sea is limited to smooth lands from the north and the east, to Ghaphghaz mountains on the west and to Talesh and Alborz mountains on the western south. Sea foam is consisted of two hollows, in centre and the north of smooth lands that is related to the northern smooth lands. Figure 1 shows the profile of the Caspian Sea foam. As it is shown, there is a sudden outgrowth between the central and the southern sections. It divides the northern hollow from southern part as a defile. The Geologists believe that the outgrowth which is tail of Ghaphghaz mountains from the western north to the eastern south has finally created Balkan mountains and Kobeh Dagh on the east of the sea. From the point of Geology the southern section that is the deepest part of the Caspian Sea is a tectonically hollow and there are some activities in its bottom. Sometimes there is a volcanic action in this hollow. Some geologists try to relate the fluctuation of the Caspian Sea to geological factors for the mentioned reasons (Rich, 1992).

2- THE CASPIAN SEA RIVERS

There are many rivers discharging to the sea having different inflow hydrographs. These rivers are located in the western north and west section of the sea and on the east there are only two rivers, Atrack and Gorgan. The yearly volume of internal rivers to the Sea is at least 212 km^3 and maximum 379 km^3 from 1935 to 1965 (Madh-Farimani, 1993).

2.1 The southern Rivers of the Caspian Sea

This part of the sea is consisted of the Alborz, Sabalan and Talesh catchments that enter about 11.64 to 12.1 km^3 water to the sea, yearly. This measure is about 4 to 5 percent of whole yearly internal water to the sea. Sephid-Rood, Chaloos, Haraz, Babol, Talar, Tajan, Neca, Gorgan and Atrack are the most important rivers of this area. The length of Sephid -Rood that is the fullest water river of this area, is 780 km and the catchment area is nearly 27000 km^2. It yearly inflows 4 km^3 water to the sea that is equal to 1.3 percent of the total inflow discharge. With

regard to all internal water by the southern rivers of the Caspian Sea that make 4 to 5 percent of the whole yearly internal water and also other rivers belong to the northern area of the sea, it is concluded that only the northern countries of Caspian Sea have a fully control on the Caspian.

Table 3 Area of the sea relative to the sea level by Ahangar (1991).

Level of sea relative to the open sea (m)	Area of Water sea level
-32.3	311000
-30.4	338600
-28.6	364300
-28.4	370000
-28	377100

2.2 The northern Rivers of Caspian Sea

Table 4 shows the main specifications of the northern rivers. Important rivers with yearly inflows of 7 km^3 to the sea from other countries are consisted of: Emba River with the length of 587 km in Ghazaghestan and Koma with the length of 430 km rising from mountains located in the Black Sea. Table 5 makes clear the average inflow discharge to the Caspian Sea by its rivers from 1935 to 1965.

3- HISTORY OF THE CASPIAN SEA LEVEL

In 1840 the level of the sea was -25.64 m and for 90 years (1930) the degree of the fluctuation was not more than 1 meter. In fact it was changing between -25.64 to -26.30 meters. However, rising water level has an unnatural process from 20 years ago. As a result it has been observed that, this rising is instantaneous or stochastic rather than deterministic and it is impossible to provide a clear return period for it. Figure 2 illustrates the curve of Caspian Sea level presented by Navigation office of Anzali port from 1926 to 1997.

The level decreased to -27.73m (from 1929 to 1941), -28.48m (from 1941 to 1970) and-29.73m (from 1970 to 1977). On the whole, in the first period the reduction was about 0.75 meter, and in the last period having about 0.65 meter decrease, Caspian Sea level reached the minimum level of statistics period; therefore, it had about 3.21 level decrease in nearly 50 years, (annual average of 6.69cm reduction). From 1977 to 1987, the level increased about 1.08 meter and reached -28.82m. This increase continued to the end of 1994 and the sea level increased.

As it shows, the level of the sea reached the maximum measured level (-25.92 m) in 1929, from that time the level decreased about 3cm (equal to -6.79 m below open level). According to the recorded statistics in the mentioned office from the March to Nov. 1995, the Caspian Sea level increased about 9cm and the sea level reached -26.70m but suddenly the sea water returned back about 20cm and the level reached -26.90m (from Nov. to the end of 1995). In 1996, the Caspian Sea level decreased about 18cm and reached -27.12m in July 1997. Most researchers believe that this drawback of the sea is a temporary introversion and the level may return back to rising. Probably the Caspian Sea level will increase again and the

Fig.1 The profile of the sea foam by Ahangar (1991).

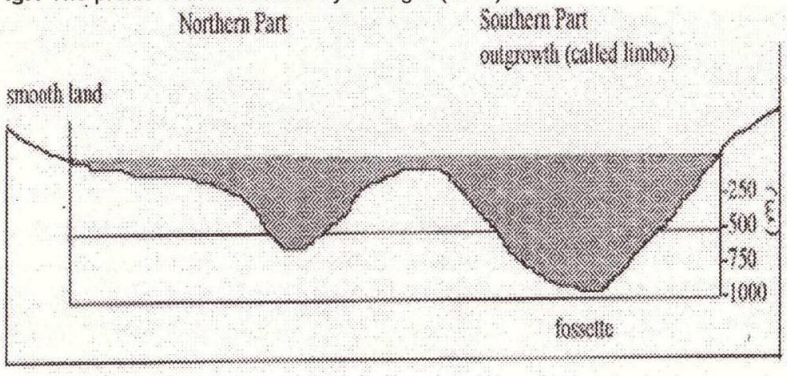

Table 6 The inflow water of Volga and its percent to the whole sea inflow

Year	Surface water Inflow (km^3)		Surface water Inflow (%)	Raining to the sea		Total inflow and outflow		Outflow to Ghareh Boghaz	Penetration (influence) (Km3)
	Volga	Total		(mm) in year	(Km^3) in year	evaporation	(Km^3)in year	(km^3)	
(1900-1929)	250.6	335.7	74.6	173	69.8	697	405.5	54	4
(1930-1941)	200.5	268.6	74.6	185	72.9	1004	314.5	32	4
(1942-1969)	241.2	285.4	84.5	200	74.1	964	359.5	29	4
(1970-1977)	207.6	240.5	86.3	243	87.6	1039	328.1	20	4
(1976-1982)	274.3	310.9	88.2	257	93.1	979	404	7	4

This rising has taken place with 17cm - annual intrusion, in the first five years, and with 7-10cm- annual intrusion in the second five years. Therefore, it is concluded that the main reason for the Caspian Sea level rising is the increase in inflow water of Volga to the sea.

B) Atmospheric falls

As the area of Caspian level is about 12% of total area of the sea catchment, it is concluded that the volume of atmospheric falls on the sea level is much less than internal inflow hydrograph of the rivers. The most AAP rainfall in the western south of the sea is in Anzali port (1543mm AAP), and then in Astara port, Lankran and Ramsar (1265mm AAP), but the least AAP is in the east especially in Ghareh Boghaz Gol and Crasnovadesk port (102mm AAP).

The measures of falls decrease from west to east and from south to north and from western south to eastern north, but the temperature increases. So the most evaporation of the sea is in the eastern middle especially in Boghaz Gol that is affected by hot weather of central Asia desert and very hot land of Ghareh Ghoom. Table 7 shows the AAP and the annual evaporation of water table in specified period.

C) Role of Evaporation in falling water table

In the equation of sea balance-sheet the evaporation is in fact the total external parameter of the Caspian Sea level. Long term average of evaporation in statistical period (1900-1982) equals 964-1039mm in a year. The highest degree of evaporation is in the north of the sea. In southern part of the sea, the least measure of evaporation (890mm in a year) belongs to the areas located between Anzali port and Lankran, because of being deep. For high temperature and low depth area of the sea, the degree of evaporation increases towards the east of the

Table 7 The AAP and evaporation of water table by Madh-Farimani (1993).

Year	Duration(year)	AAP(mm)	Yearly evaporation(mm)
1878-1894	16	177	950
1942-1969	27	200	964
1970-1977	7	236	1039
1978-1982	4	256	979

sea, so that in Ghaphargee located about 30km to Bandar Torkaman, it is 1132mm in a year. For especial topography condition of the Caspian Sea, it is concluded that the annual losses of evaporation of water table is the main reason of sea balance- sheet. It can be balanced by controling the losses of evaporation, especially in the condition of falling inflow water to the sea. It is possible to do this in the less deeper part of the sea in which there is maximum losses of evaporation, mostly in the eastern north and the east of Caspian Sea. Regarding the mentioned problem and the establishment of several dams on the rivers reaching the Caspian Sea, Estalin set thinking to balance water table and reach it to clear level in 1950. It means that several long channels were built on some of the full-water rivers located in the center and west of former Soviet Union which have no more use, and guided them to move toward the Caspian Sea, as well as closing the enter rance part of the Ghareh Boghaz Gol.

D) Ghareh Boghaz Gol

It is located in the eastern part of the sea in a region near Ghoom deserts in Torkamanestan. It is connected to the Caspian Sea by Agee Chay with 158m width and 3m depth that is caused to evaporate water. The water of this Golf is salty, thick and also its salt is settled regularly. The degree of the salt dissolved in the water is 300 to 1000, but the degree of salt in the Caspian Sea is 13 to 1000. This Golf evaporates yearly about 8-10 $km^3$of the sea water. Its area was about 18300 km^2 in 1930, decreased to 13000 km^2 (1980) and reached 10500 km^2 (1990), in this year its maximum depth was 3.5 meters. According to the experts, water table decreased about 3 meters for this Golf from century to 1980 according to Rich (1992). In the 2nd March of 1980, the Golf entrance was closed by four huge doors whose widths are 5 meters and lengths are 8 meters. By this action, the most essential parameter of loosing sea water is lost and it prevents annually 8-10 km^3 of water to the golf; entering so, the height of water table increased yearly about l2-15cm. Water table rose more in 1981 (about l25cm) and many industries and fishing of Torkamanestan were flooded.

5- RESULTS AND PROPOSALS

The Caspian Sea fluctuations depend on inflow and outflow water such as whatever happens in every closed source. The control of the inflow water is more actual and economical than outflow water that is taken place only on evaporating condition. Regarding economical terms, on the whole, the Caspian Sea level should be fixed and its fluctuations should be prevented. Considering the mentioned points in this essay, the main factors of rising water table are briefed below:

1. Deviation and guidance of northern rivers of former Soviet Union to the Caspian Sea.
2. Decrease and internal inflow of Volga to the Caspian Sea. The average inflow of Volga was 7500 m^3/s (1900-1987), but it reached 8500 m^3/s from 1978 to now.
3. Climatologic changing of region and increasing atmospheric falls at the end.
4. Closing the entrance part of Ghareh Boghaz Gol.

The factors of the Caspian Sea balance-sheet are consisted of natural (hydroclimatology) and artificial.

Raising the Caspian Sea level is less related with natural factors of northern part and it is mostly affected by the artificial parameters. As mentioned before, the control of the Caspian Sea is actual for the northern countries of the sea. From 1929 that water table began to decrease, above countries did some efforts to make the water table reach the desired point. For example, closing Ghareh Boghaz Gol and deviation of several northern rivers of the Caspian Sea.

Following proposals are also researchable:

- With regards to loosing technical and scientific information and statistics. It should be avoided to establish any kind of building near sea for minimum of 50 years. It means from now to return period in order to get final Caspian Sea level. Also, considering available statistics and expert theories, it is expected that maximum and minimum Caspian Sea level equal -25.64m and -28.5m to free sea, respectively. Both these levels can be considered as a first base for establishing any kind of building on the sea side.

gueldenstaedti (Mokhayer, 1972), *A. stellatus, A. persicus, Huso huso, A. nudiventris, Silurus glanis* and, *Esox lucius* (Sattari, 1996).

Paying attention to effects of the parasite on fish organs (castration, kidney and muscle destruction...) and subsequent economic loss, it has been attempted to identify the infected fish species and determine the prevalence and mean intensity of the parasite in them.

MATERIALS AND METHODS

Twelve fish species were collected during September 1999 – 2001. About 373 samples were examined. The study area was the south–west of Caspian Sea (Guilan province–Iran). After recording biometric characteristics (table.1), the samples necropsied based on common parasitology procedures: The viscera and muscles were examined for the parasite. The alive nematodes were fixed in hot 70% ethyl alcohol and cleared in glycerine alcohol or hot lactophenol. Some histopathological samples took from muscles , put in a fixative (10% buffered formalin) and after breaking in 5 micron sections , stained with hematoxilin and eosine to study the presence of the larvae in muscles and histopathological reactions of host tissues against the parasites. Standard statistical computations (mean, SD, range, prevalence) were calculated for the all samples by Microsoft Excel.

Table1 The biometric characteristics of examined bonyfishes from south-west of Caspian Sea

Fish species	No. of fish	Mean & range of length (cm)	Mean & range of weight (g)
Cyprinus carpio	42	33.3(19-44.5)	545(120-1170)
Esox lucius	60	39.8(28.5-58)	429.8(140-1290)
Carassius auratus	42	29(20-39.5)	375(143-820)
Abramis brama	50	25(18-34)	194.6(71-450)
Perca fluviatilis	36	21.5(16.5-30.5)	164.2(40-450)
Vimba vimba persa	50	19.3(16.5-23.5)	79.4(30-149)
C. chalcoides	50	21.6(14-23.5)	100.6(21-253)
Neogobius fluviatilis	14	21.5(12.5-26.5)	122.3(22-203)
N. kessleri	12	23.8(22.4-26.5)	140.4(117-214)
N. caspius	7	13.7(12.2-15)	33(23-49)
Aspius aspius	5	-	-
Barbus capito	5	-	-

RESULTS

The prevalence (%), mean intensity and range of the *E. excisus* larvae have been presented in table2. As shown in this table, the prevalence of *E. excisus* larvae in Gobiids was more than other fish species *(Neogobius fluviatilis, 35.7%; N.kessleri, 50%* and *N.caspius, 14.3%)*. The prevalence of *E. excisus* larvae in *Perca fluviatilis* (33.3%) was also high. The prevalence of *E. excisus* larvae in other fish species was low.

The parasite was observed as coiled in cysts inside the muscles of these two fish species. The parasite was also isolated from the body cavity of *Barbus capito, Aspius aspius* and muscles, ovaries, body cavity, upon liver and testis of *Neogobius fluviatilis, N.kessleri* and *N.caspius*.

DISCUSSION

As mentioned in introduction, *E. excisus* larvae have been reported from all sturgeons and some bonyfishes of Caspian Sea, but there was not any comprehensive study on parasites of bonyfishes of the Sea. The present survey which has been carried out in a two-year period, indicated that the *E. excisus* larvae is also found in other fish species such as perch (*p.fluviatilis*), asp (*Aspius aspius*) , barb (Barbus *capito*) , some

gobiids such as *Neogobius Fluviatilis, N. kessleri* and *N. caspius*. *E. excisus* larvae are reported for the first time from these fishes in Iran.

Table 2 Destribution of prevalence, meam intensity +SD and range of examined fish.

Fish species	No. of fish	Prevalence (%)	Mean intensity + SD	Range of parasite
Cyprinus carpio	42	0	0	0
Esox lucius	60	5	5.3+7.5	1-14
C. auratus	42	0	0	0
Abramis brama	50	0	0	0
Perca fluviatilis	36	33.3	1.5+0.8	1-3
Vimba vimba	50	2.08	1+0	0
C. chalcoides	50	0	0	0
N. fluviatilis	14	35.7	8.4+10.3	1-26
N. kessleri	12	50	10.8+12.5	1-33
N. caspius	7	14.3	1	1
Aspius aspius	5	-	0	-
Barbus capito	5	-	0	-

E. excisus larvae were very long and they were found as coiled in cysts inside the muscles and also in body cavity , ovaries , upon liver and testis of the hosts .They had also rusty (bloody) appearance . So, when the consumers observe them in fish organs, they avoid consuming the fish and they throw it away. Thus, with respect to high prevalence of *E. excisus* larvae in some commercial fish species, the economic loss may be considerable. Besides, feeding sturgeons with some infected noncommercial fishes such as Gobiids, tend to transmit *E.excisus* larvae to them which may cause heavy damage of muscles and gut in sturgeons.

In the present survey, the diversity of fish species infected with *E.excisus* larvae was high which may be due to high diversity of first intermediate hosts (at least two families of oligochaetes). The big communities of second obligatory intermediate hosts (Gobiids and Cyprinids) and also high diversity of predatory fish species (paratenic hosts) have important role in life cycle of the nematode in the nature. However , it seems that the infestation of marine fish species to the *E.excisus* larvae is more prevalent than freshwater fish , since all of the five sturgeon species and also asp, barb and different gobiid species have been found to be infected with the nematode larvae but in the former study (Sattari, 1996) on ten different freshwater species (no=290), only one catfish was found to be infected with *E.excisus* larvae and also in the present study , only two freshwater fish species was found to have the parasite(with low prevalence and low mean intensity). One reason for this hypothesis is probably the presence of second obligatory intermediate hosts (roach and gobiids) in the seawater and the other reason is the simple availability of aquatic birds (definitive hosts) to large and extensive areas of sea than freshwater. It is possible that the infection of freshwater fish species (e.g. the fishes of Anzali wetland) is due to transmission of the nematode from the Sea to freshwater by migratory fish species.

In spite of the high diversity of fish species infected with *E. excisus* larvae, the abundance of the parasite is low both in freshwater and the Sea. It is probably due to the nematode larvae remaining in the organs of oligochaetes for a long time (at least 5 months) to become infective for fish. So, it is a limiting factor for abundance of the the larvae . Furthermore, most of the paratenic hosts (predatory fishes) may be large size. So, they can not be ingested by definitive hosts (cormorants).Therefore, the life cycle of the parasite may not be completed.

In histopathology, the severe destruction of tissues and infiltration of inflammatory cells were observed, which were mostly eosinophiles, macrophage and lymphocytes

and fibroblasts surrounding the focal points of lesions.

In the present study , *P. fluviatilis* was found to be more infected with the *E. excisus* larvae which is a predatory fish and ingests the second intermediate hosts and also represents a considerable proportion of the food of the common cormorant (*P.carbo*)

In the present study, *E. excisus* larvae was not isolated from *Cyprinus carpio*, *Carassius auratus* gibelio, *Abramis brama orientalis*, *Vimba vimba persa* and *Chalcalburnus chalcoides*. It may be due to the fact that, they are not predatory fishes and they do not ingest the second intermediate hosts. So, they should not be expected to be infected with *E. excisus* larvae.

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