Retrospective analysis and current state of walleye stocks and fishery on the Dagestan coast of the Caspian Sea

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Abstract. The dynamics of commercial catches, stocks and forecast values of walleye catch on the Dagestan coast of the Caspian Sea with the analysis of factors affecting the state of stocks for a long-term period is presented. Data on seasonal distribution, migration, reproduction, as well as age and size-weight composition of walleye populations in the study area are presented. The forecast of prospects for the use of walleye by fishing is given on the basis of the analysis of commercial stocks for a number of years of observations, taking into account the coefficient of total mortality, the influence of fishing load, the values of the commercial population replenishment with first-matured fish.

1. Introduction
Under the influence of both natural and anthropogenic factors, various changes occur in the ecosystem of the Caspian Sea. The impact of such changes most strongly affected the group of semidiadromous fish, due to the deterioration of natural reproduction conditions. One of these representatives of the ichthyofauna is the walleye Sander (Stizostedion) lucioperca (Linnaeus, 1758) [1, 2].

Due to the growing importance of walleye in terms of nutritional value in the consumer market, there was a need to intensify research work.

Walleye is a valuable commercial fish species in the Caspian Sea basin. In recent years, due to the deterioration of the hydrological regime in the reservoirs of Dagestan, walleye stocks remain at a low level. As a result, over the period from 1997 to 2017, the commercial stocks of walleye in the Tersk-Caspian fishery sub-district decreased from 1.008 to 0.610 thousand tons, i.e. almost 1.7 times. Under the influence of intensive fishing, changes in the structure of walleye populations occur [3].

In this regard, the relevance of work on the clarification of commercial stocks and forecasting the volume of total allowable catches of walleye on the Dagestan coast of the Caspian Sea and in the inland waters of Dagestan increases.

2. Materials and methods of research
Collection of ichthyological material, as well as office processing was carried out in accordance with traditional methods.

The object of research was the population of walleye of the Dagestan coast of the Caspian Sea. Studied quantitative (catch data) and qualitative (data on species, size-weight, age, sex composition,
growth, fatness, places, terms, and conditions of reproduction) characteristics of the fish populations for the seasons of the year in all waters of Kizlyar Bay and surrounding area between Bryansk and Suyutkinskaya Spit, and Kraynovsk coast from Suyutkinskaya Spit to the Northern tip of Chechen island. 2072 walleye specimens were subjected to a complete biological analysis.

Places, terms, breeding conditions of the studied fish, their spawning migrations and the intensity of the spawning course were determined by net, venter catches in accordance with the methodological instructions of A.F. Koblitetskaya [4, 5].

The unaccounted seizure was calculated on the basis of primary materials during the period of research fishing collected in the areas of the highest concentrations and active fishing near the Dagestan coast of the Caspian Sea in the spring and autumn seasons. The average catch of fish per fishing gear (net, venter, seine) per day was determined. Daily catches were estimated based on the number of fishing gear used for scientific purposes. Taking into account the duration of fishing, the actual number of gears in the field, the possible total catch was calculated (based on the recorded values of the average catch per effort). The resulting difference between the calculated and actual catch (according to official statistics) was taken as an unaccounted catch.

The unaccounted catch was determined by the formula:

\[ Q_n = Q_r - Q_f, \]

where \( Q_n \) – unaccounted catch, \( t \); \( Q_f \) - actual catch, \( t \); \( Q_p \) - estimated catch.

\[ Q_r = p_o \times t \times n, \]

where \( p_o \) is the average catch of one fishing gear (kg/day); \( t \) is the time of active fishing (day); \( n \) is the number of fishing gear used for scientific purposes (pcs.).

To calculate the commercial stock of walleye, the COMBI 4.0 program was used. In the COMBI 4.0 application program, a procedure for justifying and calculating the total allowable catch (TAC) of aquatic biological resources was implemented based on the use of dynamic production models.

The actual coefficients of natural fish mortality were determined as the weighted average of the coefficients calculated by equations (3), (4). These equations are constructed on the basis of growth equations of power (I.I. Schmalhausen) (3) and asymptotic (L. Bertalanfi) (4) types.

\[ v_m = 1 - at^k (T^k - t^k) \]

\[ v_m = 1 - be^{-Kt}(1-e^{-Kt}) \]

where \( k \) - constants of the linear growth equation of the power type; \( T^k, a, b \) - constants of the natural mortality equations; \( K \) - constant of the linear growth equation of the asymptotic type; \( t \) - year of life; \( e \) - base of the natural logarithm, \( e = 2.71828 \).

The number of generations semi-anadromous juveniles was assessed by results of account surveying using fry small trawl with a length of 6, 10, 25, mesh size 6 mm, codend from gas from No. 7, and a net (in shallow water up to 0.5 m) according to standard techniques [6, 7].

3. Research results

Common walleye is widespread in the Western Caspian region, but it forms mass gathering near the island of Chechen and the coast of Northern Agrakhan, where some gathering of older age categories can be traced. Walleye likes clean water with a good oxygen regime, avoids muddy places. In the Northern Caspian Sea, young walleye live in deeper places, and after spawning, they stay in shallow coastal waters [8].

Spawning of walleye occurs in the second half of April, when the water temperature in the sea is 12-15 °C, at a depth of 1.5-2.5 m. Spawning of walleye in the spring occurs with a good oxygen regime and the flowage of the reservoir. Sexual maturity in walleye occurs at the age of 3-4 years. Walleye spawning grounds are mainly located in the estuaries of fish by-pass and discharge channels in the reservoirs of the Terek system. Mass spawning gatherings in walleye are not observed [9].
During the study period (2003-2018), the value of the commercial stock of walleye averaged 0.502 thousand tons (fluctuations of 0.225-1.106 thousand tons). The highest stocks of walleye are noted on the Krainovsky coast. (Figure 1). In 2019-2020, a slight increase in the dynamics of walleye stocks is expected, which is associated with the high yield of juveniles in recent years, due to favorable environmental conditions.

Figure 1. Data on catches, stocks and TAC of walleye on the Dagestan coast of the Caspian Sea

The value of the total allowable catch (TAC) of walleye, depending on the forecast of the state of the stock, was determined at the level of 9.1-19.2 % of the stock. In recent years, walleye is actively caught by poachers, as a result, the share of unaccounted catch of walleye increases.

The catch of walleye during the observation period ranged from 0.015 thousand in 2004 to 0.084 thousand tons in 2018. Tracing the dynamics of walleye catch in the area under consideration for a long period of time, it should be noted that, since 2015, there has been an increase in fishing in the Tersk-Caspian fisheries sub-district (Fig. 2).

Figure 2. Dynamics of walleye catch in the Tersk-Caspian fisheries sub-district in 1993-2018, thousand tons
In the Tersk-Caspian fisheries sub-district, the catch of walleye varies by year depending on its concentrations. Thus, the dynamics of walleye catch by fishing area is shown in Figure 3.

![Figure 3. Walleye catch by fishing areas in the Dagestan part of the Caspian Sea](image)

The autumn course of walleye occurs in the period from September to November. The walleye in the Tersk-Caspian sub-district becomes sexually mature and capable for reproduction at 3-4 years of life.

Commercial and research catches of walleye in 2008-2018 are mainly based on the average age groups - 3-5-year-olds, the share of which ranged from 70.5% in 2018 to 95.7% in 2017, the share of 2-year-olds ranged from 0.8% (2015) to 26.6% (2009), and the maximum share of 6-8-year-olds occurred in 2018 – 23.5%. (Figure 4).

![Figure 4. Age composition of walleye on the Dagestan coast in 2008-2018](image)

The average age of walleye ranged from 3.1 in 2008 to 4.6 years in 2015, and the fatness ratio from 1.27 in 2010 to 1.49% in 2009. The average length of commercial walleye was recorded in the range...
from 35.9 in 2009 to 43.6 cm in 2015, the average weight - from 607 in 2009 to 1097 g in 2015. (Figure 5).

**Figure 5.** Length and weight of walleye on the Dagestan coast in 2008-2018

According to the literature, the walleye reaches a length of 50-120 cm and a weight of 6-10 kg, as curiosities there are walleye up to 12-15 kg in weight [10].

The dynamics of productivity of walleye fingerlings in the Tersk-Caspian fisheries sub-district in 1999-2017 is shown in Figure 6. The diagram shows that, in 2008-2012, there was a sharp decrease in the walleye reproduction, which was associated with sharp daily fluctuations in the water level. The spawning eggs of many fish species, including walleye, which spawn in large numbers coincides with the peak of the flood, dry out and die in large numbers. At the same time, the death of juvenile fish was observed, entangled in the vegetation and not having time to leave with the water breaking, was observed. However, since 2014, there has been a clear trend to increase the yield of young walleye. In 2017, environmental conditions were relatively favorable, as a result of which the reproduction of walleye increased again. Thus, the analysis of long-term data shows that the worst-yielding year for walleye was 2008 (13.4 million specimens), and the highest-yielding year was 2017 (59.6 million specimens).

In 2018, the collection of material on natural reproduction was carried out somewhat earlier than previous years (May-June instead of July-August), and therefore the number of early juveniles (billion specimens) was estimated, which amounted to 2.1 billion specimens. In the future, to compile the dynamics of the number of early walleye juveniles, studies are needed for a number of subsequent years.
Figure 6. Dynamics of the number of juvenile walleyes in the Tersk-Caspian fisheries sub-district, million specimens.

Commercial catches of walleye in 2009-2018 showed that the number fluctuated over the years. In recent years (2015-2018), the most numerous generations of four-year-olds entered the fishery, the share of which on average amounted to 47.7 % of the fishing population (fluctuations of 26.4-60.8 %) (Table 1).

Table 1. The number of age groups in the population of walleye on the Dagestan coast of the Caspian Sea in 2008-2017.

| Years | Number of age groups, % | Average (2015-2017) |
|-------|-------------------------|----------------------|
|       | 2009                    | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| 2+    | 47.2                    | 24.8 | 20.2 | 20.5 | 17.4 | 7.0  | 2.5  | 14.3 | 7.4  | 0.7  | 6.2  |
| 3+    | 31.9                    | 36.9 | 38.4 | 32.4 | 29.7 | 46.7 | 25.0 | 18.4 | 35.4 | 16.6 | 23.9 |
| 4+    | 15.7                    | 35.4 | 34.7 | 34.4 | 38.1 | 26.6 | 51.5 | 60.8 | 51.9 | 26.4 | 47.7 |
| 5+    | 5.2                     | 1.9  | 5.3  | 9.8  | 11.8 | 14.8 | 15.8 | 4.0  | 6.7  | 34.7 | 15.3 |
| 6+    | 0.0                     | 1.0  | 1.2  | 2.1  | 2.1  | 3.8  | 4.0  | 2.0  | 0.6  | 11.7 | 4.6  |
| 7+    | 0.0                     | 0.2  | 0.2  | 0.6  | 0.7  | 1.1  | 1.0  | 0.6  | 0.7  | 7.4  | 2.3  |
| 8+    | 0.0                     | 0.0  | 0.0  | 0.2  | 0.2  | 0.0  | 0.3  | 0.0  | 0.3  | 3.2  | 0.9  |

Mature walleye after spawning begins to move to places with low water temperature. In an area that does not depend on wind events, these fish feed in the summer, depending on the distribution of forage organisms in the Kizlyar Bay, the Krainovsky coast, as well as on a large area of the Northern Caspian Sea, depending on salinity. The largest gathering of walleye during this period is observed in the zone of weak salinization (up to 4-5 %) at a depth of 3-4 meters.

In modern conditions, the population of walleye, limiting biological indicators, is negatively affected by such factors as illegal catch, unaccounted catch. Such an impact on the population leads to its reduction and decrease in numbers.

According to the conducted studies, it was found that the unaccounted catch of walleye in the region ranges from 84.5 to 150.1% of the registered official statistics of commercial catches (Table 2).
Table 2. Dynamics of walleye catches in the Tersk-Caspian fisheries sub-district in 2008-2018 according to statistics and unaccounted catch, tons

| Indicator                  | Years | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|----------------------------|-------|------|------|------|------|------|------|------|------|------|------|
| Statistical catches        |       | 9.88 | 26.72| 33.18| 27.45| 38.73| 36.52| 53.58| 60.97| 77.56| 84.48|
| Actual catches             |       | 24.70| 66.81| 82.94| 68.64| 95.83| 91.31| 98.88| 125.51| 159.66| 173.19|
| Unaccounted catch          |       | 14.82| 40.09| 49.76| 41.19| 57.1 | 54.79| 45.3 | 64.54| 82.1 | 88.71|
| Share of unaccounted catch | %     | 150.0| 150.0| 150.0| 150.1| 147.4| 150.0| 84.5 | 105.9 | 105.9 | 105.0 |

To restore and preserve walleye stocks in the sub-district, it is necessary to reduce poaching by taking special protection measures during the spawning period. We also recommend organizing unimpeded migration of walleye to spawning grounds, by reducing the intensity of fishing in the spring period.

4. Conclusion
The results of the conducted studies allow to say that the population of walleye and its commercial reserves in the Tersk-Caspian fisheries sub-district are in a satisfactory condition. However, actual fishing for this object remains intense.

The highest share of walleye in commercial catches in 2018, as in previous years, will be concentrated on the Krainovsky coast (49.5 %) and to a lesser extent on the Sulak coast (36.9%).

Intensive use of walleye stocks, as well as the catch of young walleye by small-scale fishing gear can lead to a decrease in their numbers. In this regard, it is necessary to populate the walleye in suitable reservoirs for it in terms of conditions instead of low-value fish species that lived in them. It is necessary to take measures for the arrangement of artificial spawning grounds in natural reservoirs, and the obtained eggs should be transported to other places for fry breeding there.

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