Iran. J. Ichthyol. (2022) 9(3): 140-148
P-ISSN: 2383-1561; E-ISSN: 2383-0964

ORIGINAL ARTICLE

Some biological characteristics of the reproductive gild of Baikal omul, *Coregonus migratorius* (Georgi, 1775) in the Posolskiy Sor Bay

Vladislav SHATALIN*[1], Irina MORUZI[1], Aleksandr ROSTOVTSEV[2], Kirill KOZHEMYAKIN[3], Valentin TKACHEV[3]

[1]Novosibirsk State Agrarian University, Novosibirsk, Russia.
[2]Novosibirsk branch of the Federal State Budgetary Scientific Institution "VNIRO", Novosibirsk, Russia.
[3]Baikal branch of the Federal State Budgetary Scientific Institution "VNIRO", Ulan-Ude, Russia.

Correspondence
v.a.shatalin@mail.ru

Article history:
Accepted 16 November 2022

Abstract
The aim of this work is to study some biological features of the near-bottom morpho-ecological group (MEG) of Baikal omul, *Coregonus migratorius*, which spawns in the rivers of the Posolskiy Sor Bay. The fish were collected using nets set from the Posolskiy Sor Bay, Lake Baikal in the first half of September 2019-2020. A total of 116 spawners, including 54 females and 62 males were collected. During the study, the morphology and fecundity of the reproductive gild of Baikal omul in the deep-sea MEG was studied. The results showed an increase in weight indices and absolute individual fecundity. A significant increase in the length and weight of the fish were observed showing that fecundity increases with age. There were increases in average weight, total length, most body height, and absolute individual fecundity (AIF) from those reported before.

Keywords: Absolute individual fecundity, Comparative characteristic, Morpho-age variability.

INTRODUCTION

The main negative anthropogenic impact on the Baikal omul, *Coregonus migratorius* (Georgi, 1775) is overfishing, which led to a ban on its fishing in Lake Baikal and the rivers flowing it (Ministry of Agriculture of Russia 2017). The results of Petukhova's (2020) quantitative analysis of near-bottom and deep-sea morpho-ecological group (MEG) considered this fish a separate stock indicating that recruitment would not be able to restore the commercial stock to the biomass target within the next 5 years (Petukhova 2020). The low-water period from 2014 to 2017 had a negative impact on the Baikal omul, which could adversely affect the spawning areas and the larva's survival by reducing the water area of the reservoir (Garmaev & Tsydypov 2019).

Sukhanova (2004), in a molecular study of Baikal omul, concluded that the Baikal omul is a whitefish that inhabited lake and river water bodies at the site of modern Baikal. The negative anthropogenic impact, which influenced a significant reduction in its population size, creates a need for additional study of the Baikal omul's biological characteristics in current habitat conditions (Roberts 2019). The near-bottom and deep-sea MEG, a small Baikal omul group, was compared to the pelagic MEG. It inhabits the lake at depths of up to 350m. In autumn, it spawns in small tributaries of the Posolskiy Sor Bay with a spawning path from 3 to 20km long (Neronov & Sokolov 2020). It is characterized by having a higher body and caudal fin height, a long head, and a small number (36-44) of coarse gill rakers compared to other morpho-ecological groups (Smirnov 1974). Hence this work aimed to study the morphological variations of the near-bottom MEG of Baikal omul, in the rivers of the Posolskiy Sor Bay.

MATERIALS AND METHODS

Study area: Posolskiy Sor bay is located between the Bolshaya Kultushnaya River's mouths in the south and the Bolshaya Rechka River in the northeast (Fig. 1). It also locates 25km southwest of the Selenga River delta, the main tributary of the lake, which is the breeding ground of mainly pelagic Baikal omul MEG.

Fish collection and measurements: The specimens were collected using the nets set in the Posolskiy Sor Bay of Lake Baikal on the migration routes of the

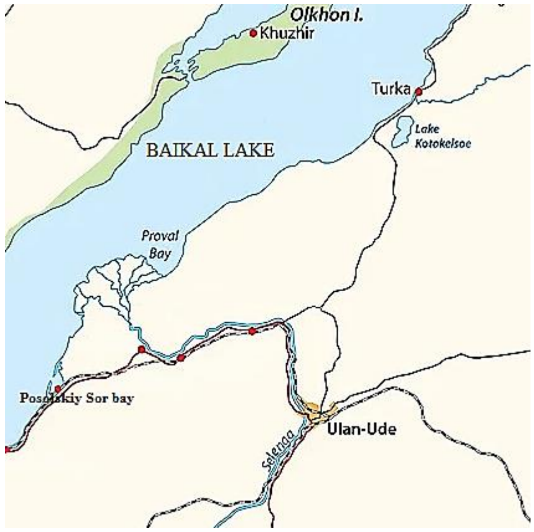

Fig.1. Posolskiy Sor bay is location.

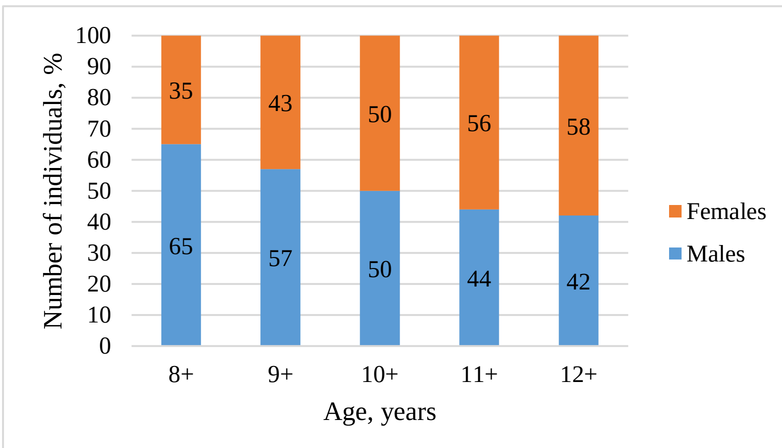

Fig.2. Percentage of sampled individuals by age (sampling was random, it is not possible to judge the overall age structure of the flock).

bottom-deep-sea spawning population in the first half of September 2019-2020. A total of 116 spawners were selected, including 54 females and 62 males. Counting, measuring (with an accuracy of 1mm), and weighting (with an accuracy of 1g) were done according to Pravdin (1966).

Scales were taken from each specimen to determine age and eggs were sampled to determine absolute individual fecundity (AIF). The age of the fish was determined based on the scales according to Smirnov & Smirnova-Zalumi (1966). Statistical analysis was carried out according to Plokhinsky (1961) by methods of quality control and variation statistics with verification of the reliability of the results.

RESULTS AND DISCUSSION

The morphological structure, size-age variability and dynamics of age fertility of producers MEG were studied. The sample was represented by reproductive specimens of Baikal omul near-bottom MEG had ages ranging 8^+ to 12^+ years that are in a depressive state of numeracy. The age percentage ratio of the females and males in the sample ranged from 35 to 58% for the females, and 42 to 65% for the males (Fig. 2).

Regardless of sex and age, the average total length of breeding specimens was 367±2mm; they had an average weight of 607±11g. The females had a total length of 378±3mm and a weight of 669±15g, and males 358±2mm and 553±13g, respectively (Table 1). By comparing the data obtained with that

Table 1. Morpho-age variability of traits.

Age, years	L, mm		Lsm, mm		l, mm		W, g	
	M±m	Cv	M±m	Cv	M±m	Cv	M±m	Cv
Females								
8+	378±6.9	5.5	343.8±4.2	3.7	329.7±4.9	3.7	523.6±18.5	10.6
9+	399±3.9	3.6	372.6±3.3	3.0	353.9±3.6	3.0	632.8±21.6	11.8
10+	412±4.2	3.6	380.1±4.3	3.9	363.2±4.2	3.9	669.3±20.5	10.6
11+	426±1.6	1.2	392.5±1.4	1.1	374.5±0.9	1.1	738.8±32.7	14.0
12+	433±4.1	3.1	397.5±4.2	3.5	380.6±4.6	3.5	764.5±23.5	10.2
$P_{(6+ к 9+)} \geq$	99		99		99		99	
Males								
8+	365.5±1.9	2.1	336.4±4.3	2.7	318.6±2.5	4.3	450.9±10.6	9.7
9+	383.4±2.6	2.8	352.9±2.4	2.7	335.1±2.3	2.8	519.3±8.9	6.9
10+	399.3±2.8	2.4	366.6±2.5	2.4	349.1±2.5	2.5	601.0 ±19.5	11.3
11+	406.8±4.0	2.8	378.0±3.1	2.3	362.0±3.0	2.3	638.4±11.5	5.1
12+	414.3±3.5	2.4	387.0±4.2	3.1	368.0±3.6	2.8	701.3±15.5	6.3
$P_{(6+ \text{ to } 9+)} \geq$	99		99		99		99	

Note: Median (M), median error (± m), coefficient of variation (Cv, %), L - is the absolute body length; lsm - is the median body length; l - is the body length from the top of the snout to the base of the caudal fin (commercial length), Q - is the body weight.

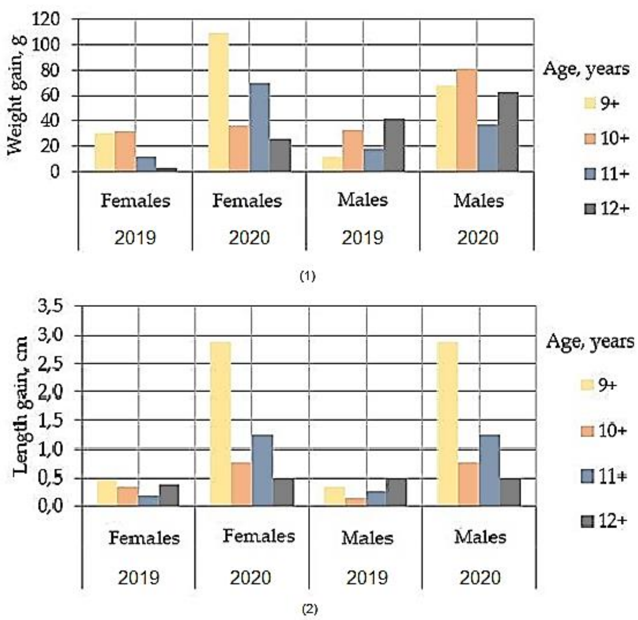

Fig.3. Comparative Smith L cm Length gain (1) and Weight gain W (2) with males and females in 2019 and 2020.

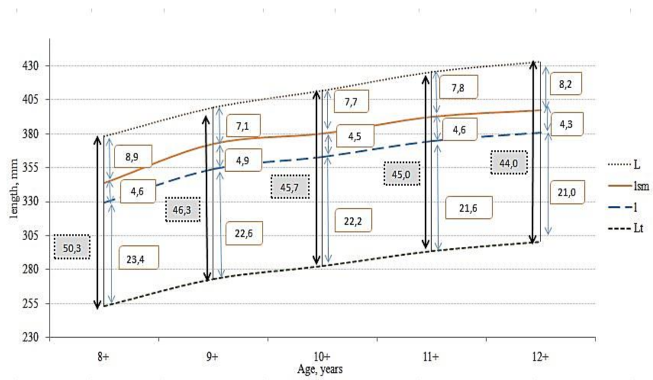

Fig. 4. Variation of linear traits with corridors of interpretation of females with age (Note: L - is the absolute body length; lsm - is the median body length; l - is the body length from the top of the snout to the base of the caudal fin (commercial length), Lt - is the relative carcass).

of 2019 (Shatalin & Moruzi 2020), there is a significant difference by age, showing a significant increase in weight and length of producers (Fig. 3).

The highest total length gain is reported for 9+ year-old individuals in both females and males at 2.9 cm, whereas in 2019 the gain for 9+ year-old individuals was 0.5 cm in females and 0.3 cm in males. The growth rate decreases with age and at age 12+, the Total length gain is close to that [recorded in 2019 (Fig. 3). The same increase in body weight of males and females was noted, more in females at the age of 9+ (108g) and 11+ years (70g) and in males at 9+ - 10+ years (Fig. 3). The improvement in growth rates suggests that omul, under the anthropogenic impact of declining stock status, is undergoing morphological changes due to gild dilution and release of the feeding area. In 2018, there was an overall trend over the past 30 years of increasing line-weights of omul, stabilizing and even improving growth and maturation rates amid declining stock status (Sokolov & Peterfeld 2018). In 2020, 4 years after introducing the fishing ban, increased linear-weight indicators and growth

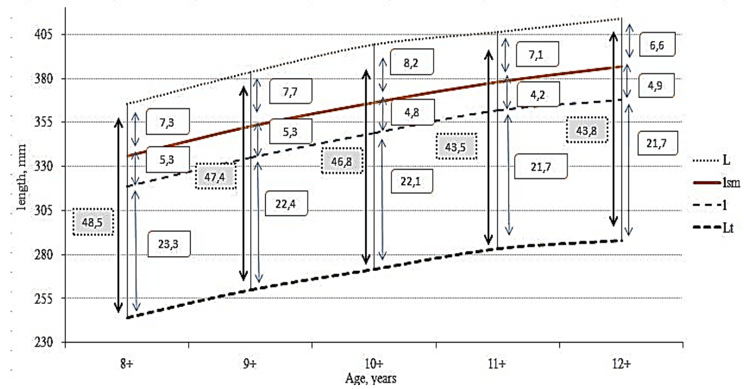

Fig.5. Variation of linear traits with corridors of variation of males with age (Note: L - is the absolute body length; lsm - is the median body length; l - is the body length from the top of the snout to the base of the caudal fin (commercial length), Lt - is the relative carcass).

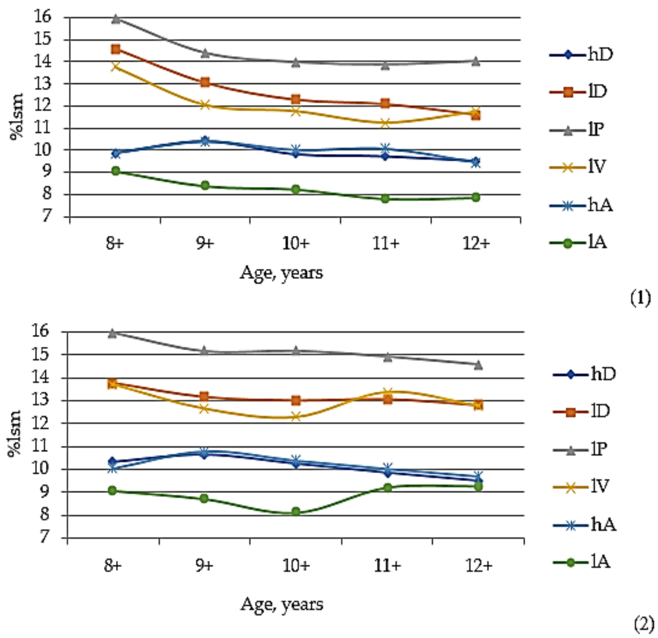

Fig.6. Change of fin length and height indices of females (1) and males (2) with age (Note: hD - is the greatest height of the dorsal fin; lD - is the length of the base of the first dorsal fin; lP - is the length of the pectoral fin; lV - is the length of the ventral fin; hA - is the height of the proctal fin; lA - is the length of the base of the proctal fin).

indicators were observed. The change in females' and males' morphometric traits with age is directed to increased absolute body length (Figs. 4, 5).

There was a relative difference in the length ontogeny between females (Fig. 4) and males (Fig. 5), which indicated linear relationships, presumably associated with sexual dimorphism. When comparing fin sizes by age, the relative length and height of fins decreased with age in both sexes, except for the anal and pelvic fins in males (Fig. 6).

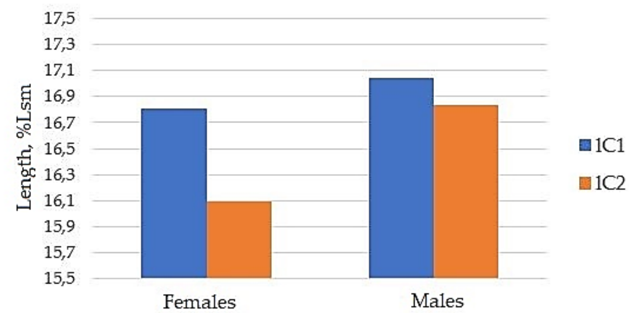

Fig.7. Relative length of the upper (lC1) and lower (lC2) tail stem blades of females and males.

The length of the upper lobe of the caudal fin is predominantly longer in females compared to the lower lobe (Fig. 6). However, the caudal fin index in males is slightly (<1%) greater.

The anal and pelvic fin length curves (Fig. 6) at ages 11+ and 12+ changed almost equally upwards. Sexual dimorphism in omul was weakly pronounced; however, the females had greater body depth and width. During the spawning period, the males had mating outfit; a rather large epithelial tubercle is formed on the lateral scales (Fig. 7). The relative head length of the studied near-bottom MEG specimens averaged 21.6±0.09%. Without regard to age, the head indices of males and females were approximately equal. With age, and decreased in near-bottom MEG from 22.2% (8+) to 20.4% (12+) and relative carcass length increased from 72.9% (8+) to 75.1% (12+), r = - 0.9 (Fig. 8).

Meristic features: The number of gill rakers in the specimens of near-bottom (multirakered) omul was 40.4±1.5. According to the 1962-1965 data, it was

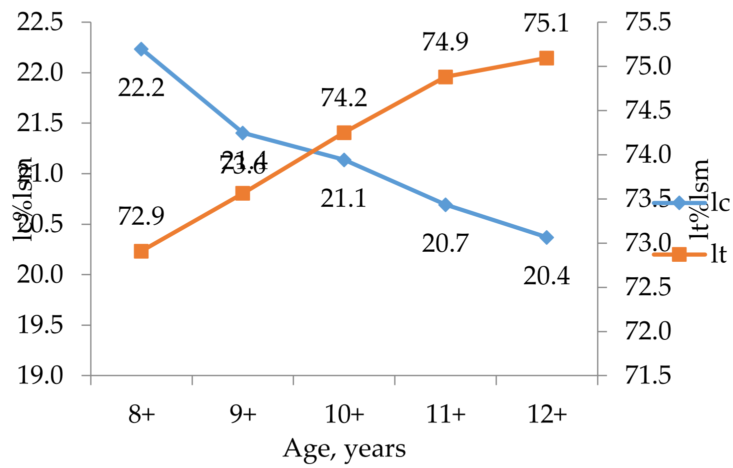

Fig.8. Changes with age in the relative head (lc) and carcass (lt) lengths of near-bottom MEG producers.

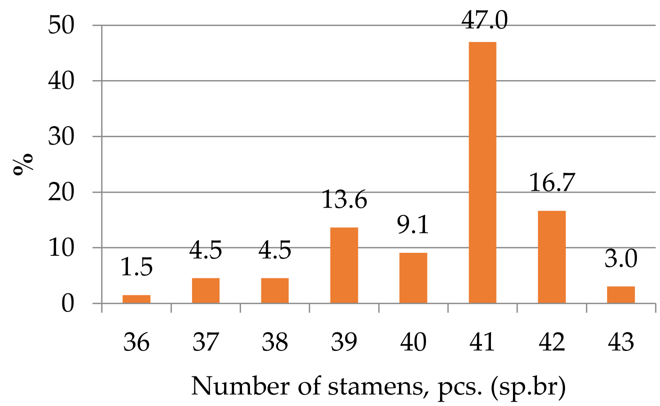

Fig.9. Percent distribution of individuals by the number of stamens on the first-gill arch.

Table 2. Number of rows of scales and number of lateral line scales.

Trait	Total			Females			Males		
	M±m	CV	lim	M±m	CV	lim	M±m	CV	lim
ll_1, pcs	90.3±0.49	4.4	80-99	90.2±0.61	4.3	80-98	90.6±0.49	4.4	85-99
ll_2, pcs	10.8±0.08	6.1	10-12	10.9±0.09	5.5	10-12	10.8±0.15	7.1	10-12
ll_3, pcs	12.4±0.08	5.5	11-14	12.3±0.10	5.3	11-14	12.5±0.14	5.7	12-14

Note: ll1 - number of scales in the lateral line; ll2 - number of scales above the lateral line; ll3 - number of scales below the lateral line.

41.42±0.22 (Smirnov & Shumilov 1974). Our data's difference is insignificant and may indicate that the near-bottom and deep-sea morphological group of Baikal omul remains unaffected by feeding adaptations. The minimum number of gills rakers on the first-gill arch was observed in 1.5% of specimens as 36, and a maximum of 43 rakers was observed in 3% of specimens. The main percentage of specimen's distribution by the number of rakers range 39 to 42. The highest number of specimens (47%) had 41-gill rakers, with 39% of specimens distributed among 39, 40, and 42 rakers (Fig. 9). The number of scales in the lateral line averaged 90±0.5 (80 to 99). The number of rows under the lateral line was 12.4±0.08 (11-14), and above the lateral line, 10.8±0.08 (10-12) (Table 2).

Fecundity: The increase in AIF has a critical adaptive value aimed at increasing gild abundance (Moruzi 2017). In 2019, the AIF was 18572 (Shatalin & Moruzi 2020). The AIF was 19903±549. The observed fluctuations in fecundity probably connect with the expansion of the feeding area, with a decrease in the population size. The tendency of AIF increase was observed in pelagic

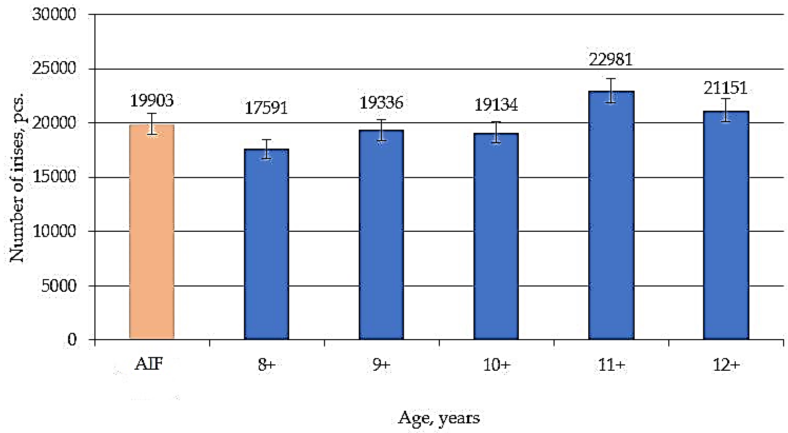

Fig.10. Age fecundity.

Table 3. Age fecundity of females.

Age, years	W, g		Absolute fecundity, pcs.		Relative fecundity to W, pcs.	
	M±m	Cv	M±m	Cv	M±m	Cv
8+	523.6±18.5	10.6	17591±326	6	33.83±1.01	8.92
9+	632.8±21.6	11.8	19336±1122	20	30.38±1.09	12.48
10+	669.3±20.5	10.6	19134±952	17	28.48±0.93	11.33
11+	738.8±32.7	14.0	22981±1397	19	31.41±1.87	18.79
12+	764.5±23.5	10.2	21151±526	8	27.81±0.71	8.43
$P_{(8+\ to\ 12+)} \geq$	99		99		99	

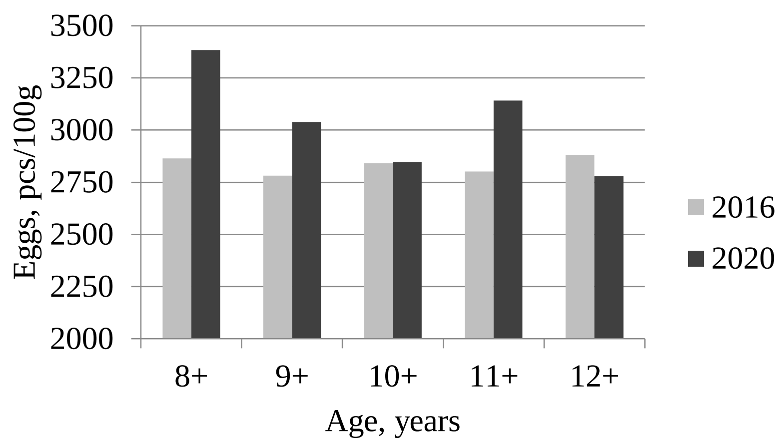

Fig.11. Comparative analysis of relative individual fecundity.

Baikal cisco MEG (Shatalin et al. 2020). The 8+-year-old individuals had an AIF of 17591±326 eggs. With age, there was an increase in fecundity as ~1644 eggs in 9+ - 10+-year-old individuals and ~4475 eggs in 11+ - 12+-year-old individuals compared to 7+-year-old individuals (Fig. 10).

The results of variance for age's effect on fecundity, group averages by age differed significantly F=4.16 > F critical =2.56, *P*= 0.005. Calculation of relative individual fecundity showed that it decreased relative to total body weight from 33.83 units/g (8+) to 27.81 units/g (12+) (Table 3). Comparative analysis of 2019 data with 2020 data showed that relative individual fecundity was higher in 2020, except for 10+ and 12+ yearlings, i.e. their numbers remained virtually unchanged (Fig. 11). There were increase in average weight, commercial length, total length, body height, and absolute individual fecundity (AIF). All this hapained despite decreasing the number of gild, and the feeding area remains the same due to changes in the food supply (Kravtsova et al. 2021).

The results of our study are also consistent with Bychenk et al. (2009), which notes that the biological characteristics in general over the past 30 years show a trend of increasing weight indicators of omul, stabilization, and even growth improvement and maturation hands despit declining its stock. In 2020, 4 years after the fishing ban, increasing lenght-weight and growth rates were continious. This may indicate that the abundance of the near-bottom and deep-sea morpho-ecological group entering (Yassumoto et al. 2020). The following relative traits decrease with age were horizontal eye diameter; most height of dorsal fin; pectoral-fin length; head length.

There is a significant increase in the size and weight of fish. The relative carcass length also increases. Sexual dimorphism in the morphometric data was weak. Females were larger than males. The mating habits of males in the spawning period are represented in the form of small groups (Nikiforova et al. 2020). Changes in biological indicators (an increase in fertility and growth rate) are one of the indicators of the state of the stock and a "protective" mechanism for preserving, maintaining and restoring numeracy.

Similar to findings of Kunnasranta et al. (2021), in our data the main problem of the Baikal omul population reduction is illegal, unregulated, and unreported fishing. Poaching has a "predatory" nature, withdrawing the stock, including individuals who did not have time to spawn (Harasti et al. 2019).

ACKNOWLEDGEMENTS

The study was performed with financial support from the Russian Foundation for Basic Research within the scientific project framework No. 19-34-90097.

REFERENCES

Bychenko, O.S.; Sukhanova, L.V.; Ukolova, S.S.; Skvortsov, T.A.; Potapov, V.K.; Azhikina, T.L. & Sverdlov, E.D. 2009. Genome similarity of Baikal omul and sig. Russian Journal of Bioorganic Chemistry 35(1): 95-102.

Garmaev, E.Zh. & Tzydypov, B.Z. 2019. Level regime of Lake Baikal: status and prospects under new regulation. Bulletin of the Buryat State University. Biology, Geography 1: 37-44.

Harasti, D.; Davis, T.R.; Jordan, A.; Erskine, L. & Moltschaniwskyj, N. 2019. Illegal recreational fishing causes a decline in a fishery targeted species (Snapper: *Chrysophrys auratus*) within a remote no-take marine protected area. PLoS One 14(1).

Kravtsova, L.; Vorobyeva, S.; Naumova, E.; Izhboldina, L.; Mincheva, E.; Potemkina, T.; Pomazkina, G.; Rodionova, E.; Onishchuk, N.; Sakirko, M.; Nebesnykh, I. & Khanaev, I. 2021. Response of Aquatic Organisms Communities to Global Climate Changes and Anthropogenic Impact: Evidence from Listvennichny Bay of Lake Baikal. Biology 10(9):904.

Kunnasranta, M.; Niemi, M.; Auttila, M.; Valtonen, M.; Kammonen, J. & Nyman, T. 2021. Sealed in a lake–Biology and conservation of the endangered Saimaa ringed seal: A review. Biological Conservation 253.

Moruzi, I.V. 2017. *The Whitefish in Carp Fishponds System: Ecology, Biology, Cultivation*. Zolotoy Kolos, Novosibirsk. 150 p.

Neronov, Y.V. & Sokolov, A.V. 2002. *Fish and Fishery of Buryatia*. BSC, Ulan-Ude. 36 p.

Nikiforova, A.; Zamaratskaia, G.; Pickova, J. 2020. Fatty acid composition of salted and fermented products from Baikal omul (*Coregonus autumnalis migratorius*). Journal of Food Science and Technology 57(2): 595-605.

Order of the Ministry of Agriculture of Russia No. 450. August 29, 2017. On amendments to the fishing rules for the Baikal fishery basin. Retrieved from: https://rg.ru/documents/2017/09/21/minselhoz-prikaz450-site-dok.html

Petukhova, N.G.; Bobyrev, A.E. & Sokolov, A.V. 2020. Results of the analysis of the near-bottom and deep-sea morpho-ecological group of Baikal omul (*Coregonus migratorius*). Fishery Issues 21(3): 283-294.

Plokhinsky, H.A. 1961. *Biometry*. Nauka, Novosibirsk. 488 p.

Pravdin, I.F. 1966. *Guidelines for the Study of Fish*. Food Industry, Moscow. 385 p.

Roberts, S.L.; Swann, G.E.A.; McGowan, S.; Panizzo, V.N.; Vologina, E.G.; Sturm, M. & Mackay, A.W. 2018. Diatom evidence of 20th century ecosystem change in Lake Baikal, Siberia. PLOS One 13(12).

Shatalin, V.A.; Moruzi, I.V. & Nekrasov, A.S. 2017. Distribution of fecundity and some biological traits of spawning stock of Baikal omul the bottom-deep-water morpho-ecological group of the Bolsherechensky fish farm. Fish breeding Breeding and fisheryFishery 1(133): 25-29.

Shatalin, V.A.; Moruzi, I.V.; Rostovtsev, A.A.; Peterfeld, V.A.; Bazov, A.V.; Konovalova, V.V. & Tsyrendylykova, M.Ts. (2020). The morphological characteristics of the reproductive gild of Baikal omul (*Coregonus autumnalis migratorius* (Georgi)) in the Selenga River (2020). Eurasian Journal of Biosciences 14: 5499-5505.

Smirnov, V.V. &, Shumilov, I.P. 1974. *Baikal omul*. Nauka, Novosibirsk. 405 p.

Smirnov, V.V. &, Smirnova-Zalumi, N.S. 1993. *Formation of annual growth zones on scales of Baikal cisco Coregonus autumnalis migratorius* (Georgi). Voprosy. Ichthyology 33(1): 121-129.

Smirnov, V.V.; Smirnova-Zalumi, N.S.; Sukhanova, L.V. 2009. *Macroevolution of Baikal omul Coregonus autumnalis migratorius* (Georgi). Siberian Branch of RAS, Novosibirsk.

Sokolov, A.V. & Peterfeld, V.A. 2018. On the reasons for the prohibition of commercial fishing of omul (*Coregonus autumnalis migratorius*, Georgi) of Lake Baikal in the modern period. In: Proceedings of the VI International Baltic Marine Forum, KSTU, Kaliningrad, p. 7.

Sukhanova, L.V. 2004. Molecular phylogenetic study of Baikal omul *Coregonus autumnalis migratorius* (Georgi). Siberian Branch of RAS, Novosibirsk.

Sukhanova, L.V.; Smirnov, V.V.; Smirnova-Zalumi, N.S.; Kirilchik, S.V. & Shimizu, I. 2004. Grouping of Baikal omul Coregonus autumnalis migratorius Georgi within the C. lavaretus complex confirmed by using a nuclear DNA marker. Annales Zoologici Fennici 41: 41-49.

Yassumoto, T.I.; Nakatsukasa, M.; Nagano, A.J.; Yasugi, M.; Yoshimura, T. & Shinomiya, A. 2020. Genetic analysis of body weight in wild populations of medaka fish from different latitudes. PLOS One 15(6).

Iran. J. Ichthyol. (2022) 9(3): 140-148
P-ISSN: 2383-1561; E-ISSN: 2383-0964
http://www.ijichthyol.org

doi: 10.22034/iji.v9i3.816
dor: 20.1001.1.23831561.2022.9.3.2.1

مقاله کامل

برخی صفات زیست‌شناختی تولید مثل اُمول طلایی بایکال *Coregonus migratorius* (Georgi, 1775) در خلیج پوسولسکی‌سور

ولادیسلاو شاتالین*[۱]، ایرینا موروزی[۱]، الکساندر روستوفتسف[۲]، کریل کوژمیاکین[۳]، والنتین تکاچف[۳]

[۱]دانشگاه دولتی کشاورزی نووسیبیرسک، نووسیبیرسک، روسیه.
[۲]بخش نووسیبیرسک موسسه علمی بودجه ایالت فدرال "VNIRO"، نووسیبیرسک، روسیه.
[۳]بخش بایکال موسسه علمی بودجه ایالت فدرال "VNIRO"، اولان اوده، روسیه.

چکیده: هدف از این تحقیق، بررسی برخی ویژگی‌های زیست‌شناختی گروه ریخت-اکولوژیک نزدیک به عمق (MEG) اُمول بایکال *Coregonus migratorius* است که در رودخانه‌های خلیج پوسولسکی‌سور تخم‌ریزی می‌کند. ماهی‌ها با استفاده از تورها از خلیج پوسولسکی‌سور، دریاچه بایکال در نیمه اول سپتامبر ۲۰۲۰-۲۰۱۹ جمع‌آوری شدند. در مجموع ۱۱۶ قطعه ماهی بالغ؛ شامل ۵۴ ماده و ۶۲ نر جمع‌آوری شدند. در طی مطالعه، ریخت‌شناسی و هماوری گروه ماهی‌های اُمول بایکال MEG اعماق دریا مورد مطالعه قرار گرفت. نتایج بیانگر افزایش شاخص‌های وزنی و هماوری مطلق فردی بود. افزایش قابل توجهی در طول و وزن ماهی مشاهده شد که نشان داد با افزایش سن، هماوری افزایش می‌یابد. میانگین وزن، طول کل، بیشترین عمق بدن و هماوری مطلق فردی (AIF) نسبت به گزارش‌های قبلی، افزایش داشت.
کلمات‌کلیدی: هماوری مطلق فردی، صفات مقایسه‌ای، تغییرپذیری سنی-ریختی.