

## THE RESEARCH IN FISH GENETICS IN CROATIA AND FORMER YUGOSLAVIA

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### *Summary*

This is a review on fish genetics research in Croatia and former Yugoslavia, based on the analyses of all the articles published in four main journals (Ribarstvo Jugoslavije, Morsko ribarstvo, Ichthyologia and Acta Adriatica) since 1945 till disintegration of Yugoslavia in 1991. Most of the papers cover the fields on cytogenetics and hybridization (24 and 13 respectively). Eight papers were on fish selection and five on population genetics. Apart from those, five papers were written by foreign authors.

Two groups of researchers from the University of Sarajevo were specially active. One of them lead by Berberović and Sofradžija did extensive work in cytogenetics, analyzing the karyotypes of many fish species, some of them endemic. Another one lead by Vuković, investigated some natural hybrids and created many of them artificially, particularly among cyprinids. These results are presented in a special table. Contrary to the mountainous Bosnia where this type of research was of systematic and ecologic importance, in Croatia whwrrw aquaculture was highly developed, the approach was quite different. The scientists from the University of Zagreb, Habeković and Turk, studied the hybridization and selection of important cultured cyprinids. Apart from these scientific groups, many papers were published by Al-Sabti, who later became world famous in fish cytogenetics. The works of many other authors who contributed with papers in different fields of fish genetics are also described.

*Key words: fish, genetics, cytogenetics, hybridization, selection, population, Croatia, Yugoslavia*

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## INTRODUCTION

The fish genetics is an important field of fishery science to which the scientists of Croatia and former Yugoslavia gave also their contribution. The name of dr. Kabil Al-Sabti is as well known among the world experts today as dr. Tihomir Vuković's one was famous in his time. The aim of this paper was to present all authors and their works in one place.

The covered period is from the end of the Second World War in 1945 till the disintegration of former Yugoslavia in 1991, and all the articles published in four main fishery journals in that period. The research done or published abroad is not taken into account (i. e. Mrakovčić & Haley 1979, Al-Sabti 1986), as well articles published after 1991 (i. e. Teskeredžić et al. 1991, Treer 1993), but it is possible to get a complete picture as every author who published abroad, did the same at home.

The journals researched are Ribarstvo Jugoslavije (meaning The Fisheries of Yugoslavia), Morsko Ribarstvo (meaning Marine Fisheries), Acta Adriatica and Ichthyologia. All four journals exist also today and are issued regularly. The first three are published in Croatia (Ribarstvo Jugoslavije changed its name into Ribarstvo), while Ichthyologia is issued in Serbia. Acta Adriatica and Ichthyologia are strictly scientific journals, while the other two used to publish other types of articles, too. The Acta Adriatica and Morsko Ribarstvo were strictly focused on the marine sciences, while the other two covered complete fisheries, with more emphasis on fresh-waters.

*Table 1. The number of papers published in the period of 1945–1991, with regard to the journal and the field of genetics. The papers of foreign authors are included in brackets.*

*Tablica 1. Broj radova objavljenih u razdoblju 1945–1991, ovisno o časopisu i području genetike. Radovi inozemnih autora uključeni su u zagrade.*

Journal (Časopis) Field of Genetics (Područje genetike)	Ribarstvo Jugoslavije	Morsko ribarstvo	Ichthyologia	Acta Adriatica	Total (Ukupno)
Cytogenetics (Citogenetika)	7		17 (20)		24 (27)
Hybridization (Hibridizacija)	4		9		13
Selection (Selekcija)	8 (9)				8 (9)
Population genetics (Populacijska genetika)	1	1	2	1 (2)	5 (6)
Total (Ukupno)	20 (21)	1	28 (31)	1 (2)	50 (55)

The number of papers published in different fields of fish genetics in these journals is presented in table 1. Three of the papers cover two fields, but they

are listed out according to the dominant field. The article included into selection is by Ivasik (1967), although hybridization is one of the topics in it, too. Similarly is with Habeković (1983). The paper by Berberović (1980), having some information on hybridization, was counted in the field of cytogenetics.

## CYTOGENETICS

In the sixties, two groups of scientists from the University of Sarajevo started to publish their papers. One group did its research on fish hybridization and the other one on fish cytogenetics and, of course, some articles were published jointly. The leading scientists in cytogenetics group were Berberović Lj., Sofradžija A. and Hadžiselimović R. In their first paper (Berberović et al. 1969) they presented the results of karyotypic analysis of two species from genus *Paraphoxinus* — *P. pstrossi* and *P. metohiensis*. Both species had same diploid number of chromosomes ( $2n=48$ ). Detailed morphology of chromosomes of *P. pstrossi* is also described, while that was not possible for another species. Two years later they corrected this data into — *P. pstrossi* ( $2n=50$ ,  $NF=80$ ) and *P. metohiensis* ( $2n=50$ ,  $NF=82$ ) (Sofradžija & Berberović 1972).

These was followed by the series of papers in the following years, when the karyotypes of other fish species were explained. The species *Chondrostoma phoxinus* and *Ch. kneri* have diploid number of 50, while  $NF$  is 86 and 80, respectively. Similarly to the genus *Paraphoxinus*, the morphology of their chromosomes show a characteristic pair of telocentric homologues. Therefore these genres could be close in taxonomy (Berberović et al. 1970). In another work of the same year *Ch. phoxinus* is compared to *Rutilus rubilio*, which also had diploid number of 50 and slightly different  $NF$ , which was 84 (Berberović et al. 1970). The difference between *P.* and *P. croaticus* ( $2n=50$ ) appears in the ratio of the biggest and the smallest pairs of the homologue chromosomes. At *P. pstrossi* this number is always over 2, while at *P. croaticus* it is always lower than that (Berberović et al. 1971).

In 1972 Berberović and Sofradžija gave the systematic list of selected numerical data on chromosome complements of 49 freshwater fishes from former Yugoslavia. Apart from other sources, they presented their own results for the diploid number of *Rutilus rutilus* ( $2n=50$ ,  $NF=68$ ), *Pachychilon pictum* ( $2n=50$ ), *Leuciscus cephalus* ( $2n=50$ ,  $NF=70$ ), *L. svallize* ( $2n=50$ ),  $NF=74$ ), *L. turskyi* ( $2n=50$ ,  $NF=68$ ) and *Phoxinus phoxinus* ( $2n=50$ ,  $NF=82$ ). In the papers which followed the basic cytogenetic knowledge was described for these species — *Gobio gobio* ( $2n=50$ ,  $NF=88$ ) (Sofradžija & Berberović 1975), *Tinca tinca* ( $2n=48$ ,  $NF=84$ ) (Berberović et al. 1978), *Carassius carassius* ( $2n=100$ ,  $NF=152$ ) and *C. auratus* ( $3n=160$ ) (Sofradžija et al. 1978), as well as for *Alburnus alburnus* ( $2n=50$ ,  $NF=82$ ) and *Alburnoides bipunctatus* ( $2n=50$ ,  $NF=88$ ) (Sofradžija et al. 1979). The

last paper out of this serial gives the diploid number ( $2n=50$ ,  $NF=70$ ) of *Nemachilus barbatulus* (Sofradžija & Vuković 1979).

The papers made by this group of authors in eighties are somewhat different. Berberović (1980) reviewed the karyotypes and the possibilities of natural hybridization among 17 cyprinid species in the waters of Bosnia and Hercegovina. He concluded that such processes existed, but only inside the subfamilies. Even the artificial hybridization of species from different subfamilies did not produce viable offspring. Furthermore, the hybridization occurred only between the species with the same diploid number. The only exception was the combination of *Barbus meridionalis* ( $2n=100$ ) and *Phoxinus phoxinus* ( $2n=50$ ), from *Barbinae* and *Leuciscinae* subfamilies. Another case of natural hybridization between two subfamilies, but with the same diploid number ( $2n=50$ ) was found only with *Chondrostoma phoxinus* (*Chondrostominae*) and *Paraphoxinus alepidotus* (*Leuciscinae*).

Sofradžija et al. (1980) checked the influence of two pesticides (»Undenda« and »Simazine«) and one detergent used for washing machines on the karyotypes of two cyprinides — *Alburnus alburnus* and *Alburnoides bipunctatus*. The 0, 5% concentration of pesticides caused lower mitotic activity, chromosome aberrations and some cases of polyploidy and aneuploidy. Similar results were obtained by the use of detergent. The last two papers by the same author (Sofradžija 1984, 1987) were dedicated to the first chromosome countings and chromosome descriptions of some marine fishes from the Adriatic sea — *Scorpaena porcus* ( $2n=42$ ,  $NF=48$ ), *S. ustulata* ( $2n=34$ ,  $NF=44$ ), *Corvina nigra* ( $2n=46$ ,  $NF=48$ ), *Mullus surmuletus* ( $2n=44$ ,  $NF=62$ ), *Chromis chromis* ( $2n=48$ ,  $NF=48$ , all chromosomes were exclusively one-paired, acrocentric and telocentric) and *Gaidropsarus mediterraneus* ( $2n=28$ ,  $NF=50$ ).

In the meantime, dr. Kabil Al-Sabti finished this Ph. D. and started publishing his works. His papers which appeared in home journals have primarily »educative«, reviewing value. First two of them (Al-Sabti 1983a, b) repeated the basic genetic knowledge applied to fish. In the next ones (Al-Sabti 1983c, e, 1984b) he discussed different methods of chromosome preparation. That was one of the main topics of his further research which recently resulted in a book (Al-Sabti 1991). In one of the papers (Al-Sabti 1983d) he described the effects of water pollution on chromosome aberrations in fish and he concluded that the biggest changes are caused by benzene, the detergents, phenol and so on. The growing interest in fish gynogenesis stimulated him to write an article on the subject (Al-Sabti 1984a). Finally, he concluded this series of papers by stressing the importance of cytogenetics studies of the fish (Al-Sabti 1985).

Apart from the researchers from Sarajevo University and Al-Sabti, only two more papers were published in the field of cytogenetics. Vujošević et al. (1983) presented the karyotypes and chromosomes morphology for 9 fish species from the Danube basin. Seven species were from *Cyprinidae* family

(*Alburnus alburnus*, *Gobio gobio*, *Leuciscus cephalus*, *Rutilus rutilus*, *Blicca bjoerkna*, *Barbus meridionalis petenyi* and *Carassius auratus gibelio*), one from *Siluridae* (*Silurus glanis*) and one from *Cobitidae* (*Misgurnus fossilis*). Beside the diploid chromosome number the authors also found out that *L. cephalus*, *A. alburnus* and *B. bjoerkna* had heteromorphic sex chromosomes. Veljović et al. (1990) did similar research of the river Zapadna Morava. They checked the karyotypes of some cyprinids (*Cyprinus carpio*, *Abramis brama*, *Carassius carassius*, *Tinca tinca*, *Leuciscus cephalus*, *Barbus barbus*) and European catfish (*Silurus glanis*). The biggest changes were found out in the fish with the biggest chromosome number (*C. carpio* and *A. brama*), and it was mainly the result of the chemical pollution. As there were not the changes in the structure of chromosomes, but in their number, the researchers agreed about the adaptability of the fish to the pollution.

## HYBRIDIZATION

The first paper published on the hybridization of fish by Knop appeared in 1958. He presented the general knowledge on this topic and explained the natural hybrids as most common among cyprinids, some of them being fertile. Related species are crossed easier than the others, but the exceptions do exist.

However, most of the papers in this field were published by another group of researchers from the University of Sarajevo, lead by Vuković T., Seratlić D. and Gužina N. Natural hybrids found and described by them were *Phoxinus phoxinus* X *Barbus meridionalis petenyi* (Vuković 1963) and *Scardinius erythrophthalmus* X *Paraphoxinus alepidotus* (Vuković et al. 1971). The first one was from water in western Bosnia and had the combined parental characters. Similarly was with the second one from southern Bosnia, but with some specific characters, as one wider part of the gut and the groups of scales scattered only in some parts of the body.

The scientists from this group also tried many artificial crossings and described them. Kosorić and Vuković (1969) carried out systematic reciprocal crossings in 12 combinations among four salmonid species from the river Neretva — *Salmo trutta fario*, *S. marmoratus*, *Salmothimus obtusirostris oxyrhynchus* and *Oncorhynchus mykiss*. The viable hybrids were obtained only in combinations *S. trutta fario* X *S. obtusirostris oxyrhynchus*, while all the others died during the larval stages.

The hybrid between *Chondrostoma phoxinus* (female) and *Paraphoxinus alepidotus* (male) studied by Vuković et al. (1970) showed intermediate values of all investigated characters — the number of *vertebrae* and *branchiospinae*, as well as the length of the gut. In 1974, Vuković and Veleđar compared in detail the scales of *Scardinius erythrophthalmus* and *Leuciscus turskyi* with those of their hybrids. The differences appeared in several characters, but inside each of the species the scales all over the body were

similar. Many meristic and morphometric characters of hybrid *Pachyhilon pictum* (female) X *Leuciscus cephalus albus* (male) were studied by Seratlić et al. (1978). Some of them were more similar to those of one of the parents and some were more specific. Similar investigation was also performed on the hybrid of female *Scardinius erythrophthalmus* and male *Leuciscus turskyi* (Seratlić & Vuković 1979).

In 1978 Vuković presented the synthesis of all their similar researches of cyprinid hybrids, which survived larval stages. Fourteen pairings were described, together with the length of life of these hybrids. Guzina et al. (1979) added to that the information on tree more crossings in *Cyprinidae* family.

Contrary to the mountainous Bosnia where this type of research was of systematic and ecologic value and not of economic importance in Croatia where aquaculture was highly developed, was quite different. Turk and Habeković (1981), from University of Zagreb, studied the hybrids of important cultured fish, female bighead (*Aristichtys nobilis*) and male silver carp (*Hypophthalmichthys molitrix*), primarily on valuable culture characters. These fish were more like their mother parent, but more resistant than both of them. The survival of one year old fingerlings was better, it was easier to transport them and their growth rate was good. This investigation had long term importance, as this hybrid was introduced to the commercial production.

The last two papers in this field of research described two hybrids of *Abramis brama* (Grginčević & Pujin 1982, 1983). One of them is natural with *Blicca bjoerkna* and was found in water around the Tisa river. Most of the characters were intermediate. Another hybrid was artificially produced with *Abramis ballerus* in reciprocal crossings. In both cases the egg fertilization was about 90%, the embryonic development about 60 degree days and the most critical period, when most of the offspring died, between 23<sup>rd</sup> and 51<sup>st</sup> day. The morphological characters of hybrids are also described.

All natural and artificial cyprinid hybrids investigated by the researchers mentioned are presented in Table 2.

Table 2. A review of the natural and artificial cyprinid hybrids investigated by the researchers mentioned in this paper

Tablica 2. Pregled prirodnih i umjetnih ciprinidnih hibrida koje su opisali znanstvenici spomenuti u ovome članku.

Number of species (Broj vrste)	Species (Vrsta)	Number of other parental species (Broj druge roditeljske vrste)	
		Confirmed or most probable (*) natural hybrids (Potvrđeni ili vrlo vjerojatni (*) prirodni hibridi)	Artificial hybrids (Umjetni hibridi)
1	<i>Abramis brama</i>	4* 8* *23	2
2	<i>Abramis ballerus</i>	8	1
3	<i>Alburnoides bipunctatus</i>		10, 11, 12, 15, 17, 18, 21,
4	<i>Alburnus alburnus</i>	1*, 15, 22, 23,* 24*	17, 19
5	<i>Aristichthys nobilis</i>		14
6	<i>Aspius aspius</i>	16*	
7	<i>Barbus meridionalis</i>	21	21
8	<i>Blicca bjoerkna</i>	1*, 2, 23*, 24*, 25*	
9	<i>Carassius carassius</i>	13	
10	<i>Chondrostoma kneri</i>		3, 21, 24
11	<i>Chondrostoma nasus</i>		3
12	<i>Chondrostoma phoxinus</i>	20	3, 20, 24
13	<i>Cyprinus carpio</i>	9	
14	<i>Hypophthalmichthys molitrix</i>		5
15	<i>Leuciscus cephalus</i>	4*	3, 19
16	<i>Leuciscus idus</i>	6*	
17	<i>Leuciscus souffia</i>		3, 4
18	<i>Leuciscus turskyi</i>	24	3, 21, 24
19	<i>Pachychilon pictum</i>		4, 15
20	<i>Paraphoxinus alepidotus</i>	12, 24	12
21	<i>Phoxinus phoxinus</i>	7	3, 7 10, 18, 24
22	<i>Rutilus rubio</i>	4	24
23	<i>Rutilus rutilus</i>	1*, 4*, 8*	
24	<i>Scardinius erythrophthalmus</i>	4*, 8*, 18, 20	10, 12, 18, 21, 22
25	<i>Vimba vimba</i>	8*	

## SELECTION

In comparison to cytogenetics and hybridization of fish there was not any group of scientists who would permanently work in the field of fish selection. Consequently, the number of published papers is limited. In the fifties there was an interesting discussion on the selection of common carps (*Cyprinus carpio*) for high body depth. After checking 400 specimens (79 of them in detail) from two fish-farms, Babuder–Mihajlović (1955) suggested that the carps with the relation between body length and body depth lower than about 2, 3 should be excluded from the reproduction. These carps, she explained, had in big percentage deformed dorsal spine with many vertebrae brown together. They had lower growth rate and were probably less resistant to disease. Next year Plančić (1956) responded that such type of carps appeared only at the best fish-farms, where carps grow rapidly. So he raised the question of whether it is favorable to exclude high-bodied broodstock from the reproduction. Mihajlović–Babuder (who changed the position of names in her family name) concluded the discussion in the same year (1956) with the statement that any genetic improvement creates also the unwanted consequences. That is the reason why in selection, nice rounded carps and not abnormally high should be chosen. She repeated the suggestion about the proximal lower limit of body relationships, changing in a little bit to 2,0–2,3.

Two papers were dedicated to the rainbow trout (*Oncorhynchus mykiss*) selection. Drećun (1973) presented the results of selection on one fish-farm in Montenegro, which was conducted from 1958. The broodstock started to spawn at two years of age and females were giving about 1500–2000 eggs per 1 kg of body mass. Their offspring had speed growth with good condition and low conversion coefficient. This fish-farm did not purchase the fish from other farms any more, so the possibility of many diseases to appear, was reduced. In another paper Pohar (1979) discussed the relationship between the selection and environmental conditions in the culture of salmonids. He concluded that it is more difficult to count some genetic parameters, like heritability ( $h^2$ ) and the intensity of selection ( $i$ ) and that's why more attention was paid to the environmental conditions. This should be changed for the sake of better production.

The final two articles in this field of research are connected to common carp selection. Habeković and Turk (1981) presented some results of long-term selection programme which they were leading on several fish-farms in Croatia. The best growth was achieved with the crossbred offspring of Poljana and Grudnjak lines, while the worst was of Našice and Grudnjak lines. Higher mortalities happened at pure lines, while the highest percentage of proteins and lipids were found in specimens from Grudnjak line. Here is to be mentioned that developed Našice and Poljana lines have been widely used abroad in selection programmes, as in Hungary, and that Našice line, crossed with Dor 70 line, gives very good offspring in Israel. In the following paper Habeković (1983) reviewed the genetics of common carp in the world. She

explained the ways of heredity, as well as the methods of selection and hybridization.

### POPULATION GENETICS

In spite of numerous investigations of the fish communities in natural waters no attention was paid to this field of fish genetics. Morović (1973) was interested in enormous phenotypic variations of European eel (*Anguilla anguilla*), so he tried to explain them by reviewing relate papers. He concluded that environmental conditions had the decisive rôle, as the genotype probably had low heritabilities. Dimovski and Grupče analyzed 6 meristic and 26 morphometric characters of *Alburnus alburnus* from various waters of Macedonia. They described in detail the four existing subspecies — *A. a. macedonicus* from the Dojran lake and the river Vardar, *A. a. alborella* from the lake Ohrid, *A. a. belvica* from the Prespa lake and *A. a. strumicae* from the river Strumica. Šorić and Ilić (1987) investigated *Gobio gobio* from the river Velika Morava. The morphological characters of this species are very variable and the comparison with other populations proves that this one should be treated as subspecies *G. g. obtusirostris*. Besides the description of the species, authors also gave its important biological parameters.

Two of the papers in population genetics (Alegria–Hernandez 1985, Alegria–Hernandez & Jardas 1985) were devoted to the most important species in the fisheries of the Adriatic sea — pilchard (*Sardina pilchardus*). In these investigations, by the analysis of body and head lengths, as well as number of vertebrae and branchiospinae, the authors distinguished two sub populations of this species — from North and Middle Adriatic. They were reproductively isolated, too, by 268 m deep depression of Jabuka. The northern subpopulation was a bit smaller.

### FOREIGN AUTHORS

Several scientists from abroad also published their investigations in fish genetics in these journals. Three of the papers were from the field of cytogenetics. Golovinskaya and Cherfas (1975) reviewed the research in the natural and artificial gynogenesis from the early investigators and explained this proces. Burtzev et al. (1976) from Russia compared the karyotypes of eight species from the *Acipenseridae* family. They devided the species into two groups — one with  $2n=60$ , where belong *Acipenser stellatus*, *A. nudiiventris*, *A. ruthenus*, *Huso huso* and *H. dauricus* and another one with twice as high chromosome number: *A. gueldenstaedti*, *A. baeri* and *A. schrenki*. The authors suggested that the species with double number of chromosomes are of polyploid origin, as well as, that the genus *Acipenser* and the genus *Huso* should be united. The Hungarian authors Bozhko et. al. (1978) described thorough analysis of the karyotypes of three species from the

*Percidae* family — perch (*Perca fluviatilis*), pike perch (*Stizostedion (Lucioperca) lucioperca*) and ruff (*Acerina cernua*). This investigation confirmed that diploid chromosome number of all three species was 48 and that NF varied a little, between 88 and 90.

Out of the last two papers, one was from Ukrainian Ivasik (1967). He reported the success of mass selection of common carps in his homeland where there was improved production on fish-farms for even 25%. The use of heterosis effect by crossings of different lines produced more resistant offspring. Finally, Avsar et al. (1988) from Turkey presented an interesting research on application of Mahalanobis distance function to the morphometric separation of silverbelly (*Leiognathus klunzingeri*) stocks of a northeastern Mediterranean gulf. In order to describe different stocks using this method, they were successful in four localities of that gulf.

### Sažetak

## ISTRAŽIVANJE GENETIKE RIBA U HRVATSKOJ I BIVŠOJ JUGOSLAVIJI

U radu je prikazan razvoj genetike riba u Hrvatskoj i u bivšoj Jugoslaviji od drugoga svjetskog rata do raspada Jugoslavije god. 1991. Istraživanje se osniva na radovima objavljivanim u četiri ribarska časopisa »Ribarstvo Jugoslavije«, »Morsko ribarstvo«, »Ichthyologia« i »Acta Adriatica«. Ukupno je objavljeno 50 radova domaćih autora, uz još pet radova iz inozemstva (tabl. 1).

Svi su radovi razvrstani u četiri područja genetike — citogenetika, hibridizacija, selekcija i populacijska genetika — pa su tako i prikazani. Najveći broj istraživanja provele su dvije skupine autora sa Sveučilišta u Sarajevu, predvodene Berberovićem i Sofradžijom u području citogenetike, te Vukovićem u području hibridizacije riba. Značajni edukativni doprinos boljem poznavanju citogenetike riba ostvario je i Al-Sabti. Opisane su kromosomske garniture mnogih ribljih vrsta i, što je posebno zanimljivo, i različite mogućnosti hibridizacije (tabl. 2).

Za razliku od planinske Bosne, gdje je prvotni interes bio usmjeren na ekološko i sistematsko proučavanje, u Hrvatskoj, gdje je akvakultura bila najrazvijenija, pozornost je posvećena ekonomski važnim ribama. Habeković i Turk proveli su temeljito proučavanje hibrida ženki sivog i mužjaka bijelog glavaša, što je imalo dalekosežne posljedice njihovim uvođenjem u redovitu ribnjačarsku proizvodnju. Ovi su autori ravnali i programom selekcije šarana analizirajući linije iz Našica, Poljane i Grudnjaka, te njihove križance. Još je nekoliko autora dalo svoj prinos ovim područjima istraživanja.

Najmanje radova objavljeno je iz populacijske genetike, iako su istraživanja ribljih zajednica bila znatna, ali s drugom svrhom. Strani autori iz Rusije, Ukrajine, Mađarske i Turske predstavili su se vrlo raznolikim radovima.

*Ključne riječi: ribe, genetika, citogenetika, hibridizacija, selekcija, populacija, Hrvatska, Jugoslavija*

## LITERATURA

C=Croatian

ES=with English Summary

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