Abstract Existing data on Myxozoa parasites infecting mullets were reviewed. The validity of nine species names was updated. Sixteen species were registered during analysis of original material collected in the Mediterranean, Black, Azov, and Japan Seas in 2004–2005. A new bivalvulid myxozoan parasite, *Myxobolus adeli* n. sp., was described from the inner organs of the golden grey mullet *Liza aurata* (Risso, 1810) collected in the Mediterranean (Ebro Delta, Spain), Black Sea (Kerch Strait, Ukraine), and Azov Sea (Genichesk, Ukraine) coastal waters. It is characterized by the presence of elongated, spindle-like cysts 0.5–1.3 mm in size, filled with wide transverse-oval spores about 6.2×7.2×4.6 μm in size, with two equal polar capsules measuring about 3.0×1.8 μm and short polar filament, turned into four coils. The obtained data show that this species differs from all previously described *Myxobolus* spp. with equal polar capsules. Comparative study of *Myxobolus* spp. recorded in worldwide mullets indicates a close relationship with *M. adeli* n. sp. and *Myxobolus improvisus* Isjumova, 1964 registered in mullets. Probably, the last species includes representatives of some different species, infecting freshwater and marine hosts.

Keywords Myxozoa · Worldwide mullets · *Myxobolus* · New species

Introduction

The mullets (Mugiliformes: Mugilidae) have a worldwide distribution and inhabit tropical and temperate waters (Nelson 1984). According to current data (FishBase) the Mugilidae family includes 24 genera and 72 species, inhabiting tropical, subtropical, and the southern part of the Atlantic, Indian, and Pacific oceans. Many mullet species have comparatively trivial areas, but one of them—grey mullet *Mugil cephalus* (Linnaeus, 1758)—can be cosmopolitan, spreading including the coastal waters of Europe, Asia, Africa, Australia, America, and Oceania. Mullets have been used as a considerable source of food in different parts of the world. The importance of mullet for aquaculture and the pathologic potential of some parasites, in particular Myxosporea, motivate their detailed study. Myxosporea represents one of the important groups of parasites infecting worldwide mullets (Lom and Dyková 1992; Kent et al. 2001). So far, a few revisionary studies of parasites infecting worldwide mullets have been conducted by Paperna (1975). Twelve species of Myxozoa were reviewed by Paperna and Overstreet (1981). The genera *Sphaerospora, Henneguya, Myxidium, Myxosoma, Myxobolus, Kudoa*, infecting mullets, were revisionary studied by Sitjà-Bobadilla and Alvarez-Pellitero (1994), Jajasri and Hoffman (1982), Landsberg and Lom (1991), Eiras 2002, Eiras et al. (2005), and Moran et al. (1999).

In the last decades, geography of the mullet parasites studies and knowledge about myxosporeans infecting worldwide mullets were considerably widened. The aim of this paper is to investigate the biodiversity of myxozoans based...
on existing data and original material obtained during parasitological investigations of mullets in the Mediterranean, Black, Azov, and Japan Seas. Studies were supported by INTAS project (INTAS Ref. No.: 03-51-5998).

Material and methods

The original study was carried out on data obtained during parasitological investigations of 3,362 fish specimens. Mullets were caught in May–June and October–November 2004–2005. In the Mediterranean coastal region of Spain (Ebro River Estuary and Santa Pola Bay) 1,550 specimens of mullets belonging to five genera were dissected. In the Ponto-Azov region, Ukraine (coastal waters near Kerch, Genichesk, Berdiansk, and Mariupol), 1,498 mullets representing four genera were dissected. Material from the Japan Sea was presented by results of parasitological dissections of 314 mullets from two genera caught in the Russian coastal regions of Japan Sea (Razdolnaya River, Kievka Bay, Posiete Bay, Artemovka). Parasitological analysis was performed based on partial parasitological dissection (Bykhovsckaya-Pavlovskaya 1985). Fresh spores were fixed on slides in a glycerine jelly medium according to Donets and Schulman (1973). Spores were photographed and measured on digital images. Descriptions of the spores were based on the references of Schulman et al. (1997) and measured on digital images. Descriptions of the spores were based on the references of Schulman et al. (1997) and Lom and Arthur (2006). Live and Giemsa-stained spores were observed and measured under MBI-3 and Olympus BX50F4 microscope equipped with Analysis Pro 2.11 software.

For ultrastructural analyses, infected tissues were fixed in a 2.5 % (v/v) glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.4) for several days at 4 °C. After washing twice with 0.1 M sodium cacodylate buffer and post-fixation in 2.0 % (v/v) osmium tetroxide in cacodylate buffer for 1 h at 4 °C, the pieces were dehydrated and embedded in Epon–Araldite solution using a standard procedure (Vávra and Maddox 1976). Blocks of embedded tissues were sectioned with an LKB III ultra-microtome. Semi-thin sections were stained with methylene blue. Ultrathin sections were mounted on copper grids, double-stained with uranyl acetate and lead citrate, and examined in a JEM 100B electron microscope operated at 80 kV.

Results and discussion

Myxosporeans of the worldwide mullets

By the present time, 64 myxosporean species from 13 genera and nine families infecting 16 mullet species belonging to six genera have been registered (Table 1). Five species were identified to the genus range. The majority of myxosporeans parasitizing mullets are attributed to the family Myxobolidae. Among them, 32 and two species belong to the genera Myxobolus and Henneguya, correspondingly. Eleven species belong to the family Myxidiidae, eight representatives of Zschokkella genus, and three species belong to the genus Myxidium. Ten species were found as representatives of the family Kudidae belonging to a single genus Kudoa. The family Sphaerosporidae contains four species belonging to the genus Sphaerospora. One species from Alataspora and one from Pseudalataspora genera were registered as representatives of the Alatasporidae family. Sphaeromyxidae, Ortholineidae, Chloromyxidae, Polysporoplasmidae as well as the Sinuolineidae family are represented by single species of each genus (Sphaeromyxum, Ortholinea, Chloromyxum, Polysporoplasma).

The maximum of species richness of Myxosporea was registered in flathead mullet M. cephalus. Thirty six species of myxosporeans from eight genera were mentioned in named host. The area includes the Mediterranean basin, Red Sea, Atlantic Coast of Africa, Mexican Gulf, and Indian and Pacific Ocean coastal waters.

Golden grey mullet Liza aurata (Risso, 1810) was mentioned as the host of 18 species of Myxosporea infecting different organs of the host in the Mediterranean, Black, and Azov Seas. Leaping mullet Liza saliens (Risso, 1810) is a host of nine species of Myxozoa, found in the Black, Azov, Mediterranean, Adriatic, and Caspian Seas. Nine species of myxosporeans were also found in thinlip mullet Liza ramada (Risso, 1810) from the Mediterranean basin. Six species of Myxosporea were described in thicklip grey mullet Chelon labrosus (Risso, 1827) and in redlip mullet Liza haematocheila Temminck & Schlegel, 1845 in the Japan Sea (Russia), in Liaohe River (China), and in Black and Azov Seas (Ukraine). From the Indian shores, three species of myxosporeans were found in largescale mullet Liza macrolepis (Smith, 1846) and two species in corsula Rhinomugil corsula (Hamilton, 1822) and in yellowtail mullet Sicomugil cascasia (Hamilton, 1822). One species was described from squiretail mullet Liza vaigensis (Quoy & Gaimard, 1825), Liza parsia (Hamilton, 1822), and longarm mullet Valamugil cunnesius (Valenciennes, 1836), from Mugil japonica and keeled mullet Liza carinata (Valenciennes, 1836), white mullet Mugil curema Valenciennes, 1836 and Mugil platanus.
| Species of parasite | Species of fish | Site of infection | Localities | Sources |
|--------------------|----------------|------------------|------------|---------|
| S. sabrazesi        | L. aurata, M. cephalus | Gall bladder     | Black Sea: Sevastopol (Crimea, Ukraine); Mediterranean: Ebro Delta (Spain) | Kolesnikova and Donets (1987), Yurakhno and Ovcharenko (2008), present paper (Fig. 23) |
| M. incurvatum       | M. cephalus     | Gall bladder     | Pacific Ocean: California; New Zealand | Jajarsi and Hoffman (1982) |
| M. lee             | Mugilidae gen. sp. | Mucous of the intestine | Marine aquarium: north-east of Spain | Padros et al. (2001) |
| M. papernae         | L. macrolepis   | No data          | Indian Ocean | Dorothy and Kalavati (1992) |
| Z. admiranda        | M. cephalus, L. aurata | Gall bladder | Black Sea: Crimea (Ukraine); Mediterranean: Ebro Delta (Spain) | Yurakhno (1993, 2004), Yurakhno and Ovcharenko (2008), present paper. (Fig. 20) |
| Z. dogieli          | M. cephalus, L. aurata, L. saliens | Gall bladder | Black Sea: Novorossiysk, (Russia) | Pogoreltceva (1964) |
| Z. ganapani         | L. macrolepis   | Gall bladder     | Indian Ocean | Dorothy and Kalavati (1992) |
| Z. magna            | L. haematocheila | Gall bladder     | Liaoho River (China) | Chen and Hsieh (1984) |
| Z. muglisi          | M. cephalus     | Gall bladder     | Liaoho River (China) | Chen and Hsieh (1984) |
| Z. mugilis          | L. saliens (type host), L. ramada, M. cephalus, C. labrosus | Gall bladder | Mediterranean: Ebro Delta (Spain); marine fish farms (Italy) | Sitjà-Bobadilla and Alvarez-Pellitero (1993), Munoz et al. (1999), Quaglio et al. (2002) |
| Z. nova             | M. cephalus, L. aurata, L. saliens | Gall bladder | Black Sea: Crimea (Ukraine); Novorossiysk (Russia) | Pogoreltceva (1964), Reshetnikova (1955) |
| Zschokkella sp.     | L. saliens     | Gall bladder     | Adriatic Sea: Boka Kotorwska Bay (Montenegro) | Lubat et al. (1989) |
| O. diversa          | L. aurata      | Urinary bladder  | Black Sea: Sevastopol (Crimea, Ukraine) | Yurakhno (1993, 2004) |
| B. indica           | M. cephalus    | Gall bladder     | Backwoods of Visakhapatnam Harbor and Gosthani Estuary, Andhra Pradesh (India) | Kalavati and Anuradha (1995) |
| S. corsulae         | R. corsula     | Gall bladder     | Estuary of Hooghly River of Bengal delta near Diamond Harbor, West Bengal (India) | Sarkar and Ghosh (1991) |
| S. dicentranchi     | M. cephalus, C. labrosus, L. ramada, L. aurata, L. saliens | Gall bladder, gut, kidney | Black and Azov Seas: Kerch Strait, Sevastopol, Genichesk (Ukraine); Atlantic ocean; Mediterranean: River Ebro Delta (Spain); marine fish farms (Italy) | Yurakhno and Maltsev (2002), Quaglio et al. (2002), present paper (Fig. 21) |
| S. mugilis          | L. haematocheila | Gall bladder     | Razdolnaja River (Russia) | Asjeva (2000) |
| S. rostrata         | Mugil sp.      | Kidney           | Mediterranean: coastal waters of Italy and France | Thélohan (1985), Kudo (1919), Sitjà-Bobadilla and Alvarez-Pellitero (1994) |
| P. mugilis          | L. aurata, L. ramada, Ch. labrosus | Kidney | Mediterranean: Ebro Delta, Santa Pola (Spain); Black Sea: Sevastopol (Crimea, Ukraine) | Sitjà-Bobadilla and Alvarez-Pellitero (1995), (1996), Yurakhno and Ovcharenko (2008), present paper (Fig. 22) |
| Chloromyxum kotorensiss | L. aurata   | Kidney           | Adriatic Sea: Boka Kotorwska Bay (Montenegro) | Lubat et al. (1989) |
| Alataspora sp.      | L. ramada     | Gall bladder     | Mediterranean: Ebro Delta (Spain) | Present paper (Figs. 16, 17) |
| P. pontica          | L. aurata     | Gall bladder     | Black Sea: Sevastopol (Crimea, Ukraine) | Kovalev et al. (1989), Yurakhno (1993, 2004) |
| Species of parasite | Species of fish | Site of infection | Localities | Sources |
|---------------------|----------------|------------------|------------|---------|
| *M. achmerovi* Schulman, 1966 | *M. cephalus, L. haematocheila* | Fins, gills, mesentery | Japan Sea: Posiet Bay (Russia) | Schulman (1966), Eiras et al. (2005) |
| *M. acutus* (Fujita, 1912) Landsberg & Lom, 1991 | *M. cephalus, L. haematocheila* | Surface of scales | Japan Sea: Peter Great Bay, Tokarjevski Cape; Narva, Kijevka, Avvakumowka, Razdolnaja Rivers (Russia) | Asejeva (1994, 2000) |
| *M. adeli* sp. n. (syn. *M. improvisus* Isjumova, 1964 (in Schulman 1966 and Yurakhno and Maltsev 2002)) | *L. aurata* | Intestine, swim bladder, pyloric caeca, esophagus, stomach, gills | Black and Azov Seas: Kerch Strait, Genichesk, Sevastopol (Crimea, Ukraine); Mediterranean: Ebro Delta, Santa Pola (Spain) | Yurakhno and Maltsev (2002), present paper (Figs. 2, 3, 28) |
| *M. arctic* Sarkar, 1989 | *R. corsula* | Mesentery associated with duodenum | Indian Ocean: Bay of Bengal (India) | Sarkar (1989) |
| *M. bankimi* Sarkar, 1989 | *S. cascasia* | Gall bladder | Parganas, West Bengal (India) | Sarkar (1999) |
| *M. bizerti* Bahri & Marques 1996 (syn. *M. hannensis* Fall et al., 1997) | *M. cephalus* | Gills | Mediterranean: Ichkeul, Bizerte, Ghar El Melh; Atlantic Ocean: Baie de Gorée (Senegal) | Bahri and Marques (1996), Eiras et al. (2005), Fall et al. (1997), Bahri et al. (2003), Yemmen et al. (2012) |
| *M. bramae* Reuss, 1906 | *M. cephalus* | Gills, gill arches, skin, fins, muscles, mouth, esophagus, intestine, gall bladder, kidney, liver, spleen, heart | Azov and Black Seas: Kerch Straite (Crimea, Ukraine) | Iskov (1989), Yurakhno and Maltsev (2002) |
| *M. branchialis* (Markevitsch, 1932) Landsberg & Lom, 1991 | *M. cephalus, L. aurata, L. saliens* | Gill filaments, kidney, and spleen | Black and Caspian Seas | Schulman (1966), Ibragimov (1987), Iskov (1989) |
| *M. cephalis* Iversen et al., 1971 | *M. cephalus* | Braine meninges, gill arches, buccal cavity, jaw bone, crop tissue | Atlantic Ocean: Mexical Gulf (USA) | Iversen et al. (1971), Lom and Dyková (1992), Eiras et al. (2005) |
| *M. cheni* Schulman, 1962 | *M. cephalus, L. haematocheila* | Trunk muscles | Liaoho River (China) | Schulman (1962, 1966), Eiras et al. (2005) |
| *M. circulus* (Achmerov, 1960) | *M. cephalus* | Gills, muscles, kidney, fins, separate spores in other organs | Black Sea: Paleostomi Lake (Georgia); Lyubimovka (Crimea, Ukraine) | Naidenova et al. (1975), Iskov (1989), Yurakhno (2004) |
| *M. episquamalis* Egusa et al., 1990 | *M. cephalus* | Beneath the scales, fins, gill arches | Mediterranean: Ichkeul lagoon (Bizerte, Tunisia); coastal waters of Japan and Korea; estuaries in eastern Australia; Mediterranean: Çamlık lagoon (Turkey); Santa Pola (Spain); Atlantic Ocean: Senegalese coast | Egusa et al. (1990), Eiras et al. (2005), Lom and Dyková (1994), Bahri and Marques (1996), Rothwell et al. (1997), Bahri et al. (2003), Yurakhno and Ovcharenko (2008), Özak et al. (2012), Diamanka et al. (2008), Kim et al. (2013), present paper (Figs. 4, 7) |
| *M. exigus* Thélohan, 1895 | *M. cephalus, C. labrosus, L. aurata, L. saliens, L. ramada* | Gill filaments, gill arches, pyloric caeca, heart muscles, stomach cavity, gall bladder, intestine, kidney, mesentery, spleen, fins | Mediterranean: Marsel, Banya (France); Genova, Napoli (Italy); Adriatic Sea: Boka Kotoraska Bay (Montenegro); Tunisian lagoons; Narva and Kijevka Rivers (Russia); Caspian Sea (Middle and southern parts of Turkmenian Gulf; Azov and Black Seas (Ukraine); Atlantic ocean (France), Baie de Goree (Senegal) | Thélohan (1895), Parisi (1912), Kudo (1919), Schulman (1957, 1966), Ergens et al. (1975), Siau (1978), Pulsford and Matthews (1982), Iskov (1989), Lubat et al. (1989), Lom and Dyková (1992), Fall et al. (1997), Asejeva (2000), Eiras et al. (2005), present paper |
| Species of parasite | Species of fish | Site of infection | Localities | Sources |
|---------------------|----------------|------------------|------------|---------|
| *M. goensis* Eiras & D’Souza, 2004 | *M. cephalus* | Gills | Coast of India | Eiras and D’Souza (2004), Eiras et al. (2005) |
| *M. ichkeulensis* Bahri & Marques, 1996 (syn. *M. goensis* Fall et al., 1997) | *M. cephalus* | Gills, muscles, skin, scales | Mediterranean: Ichkeul lagoon (Bizerte, Tunisia); Lake Ichkeul (Tunisia); Camlik lagoon (Turkey); Santa Pola, Ebro Delta (Spain); Black and Azov Seas; Kerch Strait, Genichesk (Crimea, Ukraine); Atlantic Ocean: Baj de Gorée (Senegal) | Bahri and Marques (1996), Fall et al. (1997), Bahri et al. (2003), Eiras et al. (2005), Pedro-André et al. (2011), Özak et al. (2012), present paper (Figs. 5, 6) |
| *M. lisae* (Narasimhamurti & Kalavati, 1979) | *M. cephalus* | Gills, mesentery, intestine, gall and urinary bladders, liver, kidney, gonads, spleen, eyes, fins, heart, muscles | Mediterranean: Napoli (Italy), Ichkeul lake (Tunisia); Azov and Black Seas: Evpatoriya, Karandag, Sevastopol, Kerch Strait, Genichesk (Crimea, Ukraine); Atlantic Ocean: Baj de Gorée (Senegal) | Parisi (1912), Pogoreltceva (1952, 1964), Reshetnikova (1955), Bahri et al. (2003), Eiras et al. (2005), present paper (Fig. 1) |
| *M. lizae* (Narasimhamurti & Kalavati, 1979) | *L. macrolepis* | Outer wall of the gut | Indian waters at Andhra Pradesh (India) | Narasimhamurti and Kalavati (1979a), Eiras et al. (2005) |
| *M. lizae* | *L. macrolepis* | Mesentery | Black Sea: Sudak (Crimea, Ukraine) | Pogoreltceva (1964) |
| *M. lizae* | *C. labrosus* | Gill filaments | Indian coastal waters | Narasimhamurti et al. (1980), Eiras et al. (2005) |
| *M. mugauratus* (Pogoreltceva, 1964) | *L. aurata* | Gills | Mediterranean: Gulf of Tarento | Parenzan (1966), Eiras et al. (2005) |
| *M. mugchelo* (Parenzan, 1966) | *L. aurata* | No data | Mediterranean | Perugia (1891) |
| *M. mugilis* Pergaia, 1891 | *L. aurata, L. ramada* | No data | Indian Ocean: Bay of Bengal, Orissa (India) | Haldar et al. (1996), Eiras et al. (2005) |
| *M. mugilii* Haldar et al., 1996 | *M. cephalus* | Gut epithelium | Indian coastal waters | Narasimhamurti (1970), Eiras et al. (2005) |
| *M. narassii* (Narasimhamurti, 1970) | *L. vaigiensis* | Gills | Egypt; Mediterranean: Ebro Delta (Spain) | Negm-Eldim et al. (1999), Eiras et al. (2005), present paper (Fig. 14) |
| *M. nile* (Negm-Eldim et al., 2005) | *M. cephalus* | Spleen | Mediterranean: Gulf of Tarento (Italy) | Parenzan (1966), Eiras et al. (2005) |
| *M. parvus* Schulman, 1962 | *C. labrosus* | Gill lamellae, gall bladder, kidney, intestine, liver, mesentery | Liaoho River (China), Japan Sea; Azov Sea; Black Sea | Schulman (1962), Karatajev and Iskov (1984), Domnich and Sarabeev (1999, 2000), Sarabeev and Domnich (2000), Syirovatka and Nizova (2000), Eiras et al. (2005), present paper (Figs. 8–13) |
| *M. platanius* Eiras et al., 2007 | *M. platanius* | Spleen | Lagoa dos Patos (Brasil) | Eiras et al. (2007) |
| *M. raibauni* Fall et al., 1997 | *M. cephalus* | Liver | Atlantic Ocean: Baj de Gorée (Senegal) | Fall et al. (1997), Eiras et al. (2005) |
| *M. rohdei* Lom & Dykova, 1994 | *M. cephalus* | Kidney, gall bladder, intestine, mesentery, muscles | Estuary of Arrawarra creek (Australia); Mediterranean: Delta Ebro (Spain) | Lom and Dyková (1994), Eiras et al. (2005), present paper (Fig. 19) |
| *M. rotundus* Nemeczek, 1911 | *L. aurata* | Gill lamellae; heart and other inner organs | Black Sea: Paleostomi Lake (Georgia) | Donets (1979), Iskov (1989) |
| *M. spinacurvatura* Maeno et al., 1990 | *M. cephalus* | Intestine, liver, intrahepatic bile ducts and gall bladder, spleen, mesentery, | Mediterranean: Ichkeul lagoon, Bizerte (Tunisia), Lake Ichkeul in northeastern Tunisia, Delta Ebro, Santa Pola (Spain); Narva | Maeno et al. (1990), Lom and Dyková (1994), Bahri and Marques (1996), Asejeva (2000), Bahri et al. (2003), Eiras et al. (2005), present paper (Fig. 15) |
| Species of parasite       | Species of fish       | Site of infection                                                                 | Localities                                                                 | Sources                        |
|--------------------------|-----------------------|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------|--------------------------------|
| *M. supamattayai*        | *V. seheli*           | mesenteric vessels, brain, liver, spleen, pancreas, gill filaments               | River (Russia), Estuary of Arrawarra creek, New South Wales coast (Australia), Japan coastal waters | Kittichon et al., 2011         |
| *M. curema*              | *M. cephalus*         | Skin                                                                            | Andaman Sea (Thailand)                                                     | U-Taynapun et al. (2011)       |
| *M. cephalus*            | *M. cephalus*         | Heart                                                                           | Atlantic coast of Senegal                                                  | Yemmen et al. (1997)           |
| *H. ouakamensis*         | *M. cephalus*         | Heart                                                                           | Mediterranean: Ghar El Melh lagoon (Tunisia)                              | Yemmen et al. (2012)           |
| *H. sepheli*             | *S. cascasia*         | Skin                                                                            | Indian Ocean (Bay of Bengal)                                              | Sarkar and Chaudhury (1996)    |
| *K. bora*                | *M. cephalus*         | Mesentery associated with intestine                                              | Estuarine waters of West Bengal (India)                                   | Sarkar and Ghosh (1991)        |
| *K. cascasia*            | *L. parsia*           | Gall bladder                                                                     | Southeastern coast of the Kii Peninsula (Gokasho Bay, Japan)               | Maeno et al. (1993)            |
| *K. intestinalis*        | *M. cephalus*         | Intestinal musculature                                                           | Red Sea farms in Gulf of Elat (Israel)                                     | Diamant et al. (2005)          |
| *K. quadratum*           | *M. cephalus*         | Muscles, adipose tissue, nerve axons, mesentery, swim bladder, heart, pericardium, kidney, ovary | Indian Ocean: coast of India                                               | Iskov (1989)                   |
| *K. tetraspora*          | *M. cephalus*         | Musculature                                                                      | Braine, optic lobes                                                        | Narasimhamurti and Kalavati (1979) |
| *K. trifolia*            | *L. aurata, L. ramada*| Connective tissue of spleen, kidney, gall bladder, swim bladder, intestine, intestinal mesentery, gills | Mediterranean: Santa Pola (Spain)                                          | Holzer, et al. (2006), present paper (Figs. 18, 25) |
| *K. unicapsula*          | *L. ramada, L. aurata*| Intestinal mesentery, pyloric caeca                                               | Mediterranean: Santa Pola, Ebro Delta (Spain)                              | Yurakhno et al. (2007), present paper (Figs. 24-27) |
| *K. valamugili*          | *V. cunnesius*        | Intestinal musculature                                                           | Indian Ocean: Visakhaptanam harbor (India)                                 | Kalavati and Anuradha (1993)   |
| *K. valamugili*          | *L. aurata*           | Intestinal mesentery, pyloric caeca                                               | Mediterranean: Santa Pola, Ebro Delta (Spain)                              | Yurakhno et al. (2007), present paper (Figs. 24-27) |
| *K. valamugili*          | *V. cunnesius*        | Intestinal musculature                                                           | Indian Ocean: Visakhaptanam harbor (India)                                 | Kalavati and Anuradha (1993)   |
species were found in the mesenterium and intestines; two in the heart, on fins, and scales. The urinary bladder, spleen, and liver were infected with a separate species of myxozoans. Eighteen species were detected in various organs (Table 1).

There are only six cosmopolite species. All of them are parasites of *M. cephalus*. Those are *Myxobolus muelleri*, *Myxobolus ichkeulensis*, *Myxobolus episquamalus*, *Myxobolus exiguus*, *Myxobolus parvus*, and *Myxobolus spinacurvatura*.

Original data of the author’s investigations

We conducted taxonomical studies of mullet myxosporeans collected in the Mediterranean, Black, Azov, and Japan Seas in the summer and autumn 2004–2005. *M. cephalus* was parasitologically studied in all regions; *L. haematocheila*—in the Japan, Black, and Azov Seas; *L. aurata* and *L. saliens*—in the Mediterranean, Black, and Azov Seas; and *L. ramada* and *C. labrosus*—exclusively in the Mediterranean Sea.

Totally, 16 species of myxosporeans have been registered. New information about myxosporean fauna for each region of investigations has been received.

*Zschokkella admiranda* from *M. cephalus* has been registered for the first time in the Mediterranean fauna. *Sphaeromyxa sabralesi*, *Kudoa unicapsula*, *Alataspora* sp., *Z. admiranda*, *Myxobolus adeli* sp. n., *M. parvus*, *M. muelleri*, *M. ichkeulensis*, *M. spinacurvatura*, *Myxobolus rohdei*, *M. exiguus*, *Myxobolus nile*, *Myxobolus episquamalus* have been found in the coastal waters of Spain. *M. cephalus* appeared to be a new host for *S. sabralesi*. *L. aurata* was registered as a new host for *Sphaerospora dicentrarchi*. *L. ramada* and *C. labrosus* were found as hosts for *Polysporoplasma mugili* in the Mediterranean Sea. *P. mugili* infecting *L. aurata* has been found for the first time in the Black Sea. *S. dicentrarchi*, *M. ichkeulensis*, and *M. spinacurvatura* infecting *M. cephalus* was firstly registered in the Black and Azov Seas. *L. aurata* was firstly registered as a new host for *Z. admiranda*. *M. ichkeulensis*, *M. spinacurvatura*, and *M. episquamalus* parasitizing *M. cephalus* has been found for the first time in the Japan Sea.

Among mullets inhabiting the Mediterranean basin, we found several myxosporeans, already known species of parasites, which were described earlier as new species. All of them were synonymized. Species names *Sphaerospora mugili* Yurakhno & Maltsev, 2002; *Sphaerospora* sp. Quagliolo et al., 2002; and *Sphaerospora* sp. Caffara et al., 2003 were considered as younger synonyms of *S. dicentrarchi* Sitja-Bobadilla & Alvarez-Pellitero, 1992. Others species names containing synonyms are presented by as follows: *Myxobolus bizerti* Bahri & Marques, 1996 (=*Myxobolus hannensis* Fall et al., 1997); *Myxobolus ichkeulensis* Bahri & Marques, 1996 (=*Myxobolus goreensis* Fall et al., 1997), *M. adeli* sp. n. (=*Myxobolus improvisus* Isjumova, 1964 (in Schultmann 1966; Yurakhno and Maltsev 2002); *Myxobolus lizauratus* (in Yurakhno and Ovcharenko 2008).

In the present paper, we describe the following new species: *M. adeli* sp. n. from *L. aurata* in the Mediterranean, Black, and Azov Seas.

*Myxobolus adeli* sp. nov. (Table 2; Figs. 2, 3, 28)

Type host. Golden mullet *L. aurata* (Risso, 1810)

Site of infection. Intestine, pyloric caeca, esophagus, stomach, swim bladder; sporadically: gills and muscles

Locality. Mediterranean coastal waters (Ebro River Delta, Santa Pola Bay), Black Sea waters (Kerch Channel), and Azov Sea (Genichesk aquatoria)

Prevalence. Ebro River Delta, Spain, autumn 2005—11 % (8/73); Santa-Pola Bay, Spain, summer 2005—12 % (7/60); Kerch Channel, Ukraine, summer 2004—13 % (11/83), autumn 2005—11 % (4/35); Genichesk, Ukraine, summer 2004—6 % (11/188), autumn 2005—9 % (4/47)

Description. Vegetative forms: cysts are spindle form with sharpened or rounded ends, 0.5–1.3 mm in size. Spores: oval shaped, transversally widened. Widely positioned pyriform polar capsules close acquired at the anterior

| Table 2 | Comparative data of *Myxobolus adeli* sp. n. and three closely related *Myxobolus* spp. |
|-----------------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Species                                      | *Myxobolus adeli* sp. n.        | *Myxobolus improvisus*          | *Myxobolus latus*               | *Myxobolus artus*               |
| Shape and sizes of vegetative plasmodia      | Spindle-form, 0.5–1.3 mm         | Round 1.5 mm, in diameter       | Round, not more than 0.5 mm in diameter | Round or oval, not more than 0.5 mm in diameter |
| Spore length (μm)                            | 5.56–6.75                      | 6.5–7.7                         | 7.0–10.0                        | 6.5–8.5                         |
| Spore width (μm)                             | 6.57–7.77                      | 7.5–9.3                         | 8.4–11.0                        | 9.0–12.0                        |
| Spore thickness (μm)                         | 3.55–5.27                      | 5.2–5.6                         | 5.5                             |                                 |
| Polar capsule length (μm)                    | 2.36–3.8                       | 4.6–5.6 and 3.7–4.0             | 4.0–5.6                         | 4.0–6.0                         |
| Polar capsule width (μm)                     | 1.26–2.28                      | 2.0–3.3 and 2.6                 | 3.0–4.0                         | 2.3–5.0                         |
Figs. 1–28 Light microscope and ultrastructural data of some myxozoan parasitizing collected mullets. 1 Spores of M. muelleri. 2, 3 M. adeli sp. nov., spores (2) and spindle-shaped cysts of different maturity (3). 4, 7 M. episquamalis. Compact whitish masses on the distal parts of scales (4). Each cystic mass consists of numerous microcysts. Oval spores tapered at the anterior end (7). Polar capsules equal and pyriform. 5, 6 Spherical spores of M. ichkeulensis with oval polar capsules. No intercapsular appendix is visible (6). 8–13 M. parvus. Spores (8–11) and rounded-to-oval white cysts up to 2.0 mm in diameter (12, 13). Polar capsules contain four coils of longitudinally twisted polar filament (10). Two valvogenic cells form a good developed sutural ring (11). 14 Spores of M. nile with unequal polar capsules. 15 Spores of M. spinacurvatura. Polar capsules do not reach the midpoint of the spore length. 16–17 Alataspora sp. Spherical polar capsules located close to the anterior pole (16). Vegetative stages presented by rounded or oval-shaped bisporous plasmodia with transparent ectoplasm and small-grained endoplasm (17). 18 Kudoa trifolia. Four small subspherical polar capsules are located in the central part of the spore, between the spore body and leaf-like appendages. 19 M. rohdei. Spores are regularly ellipsoidal with a good developed sutural edge around the spore, bearing distinct sutural markings. 20 Z. admiranda. Round or oval diaporous plasmodia with small granular endoplasm. Oval spores with rounded poles. 21 Spores of S. dicentrarchi. 22 P. mugilis. Spores subspherical in front view. Sutural line straight. Polar capsules spherical, of equal size. 23 S. sabrazesi. Spores cylindrical, bent in arch form; with truncated ends. Polar capsules large, cylindrical. 24–27 Light and electron microscope data of the spores of K. unicapsula. K. unicapsula and K. trifolia—mix infection (25). 26–27 Ultrastructure of the spores of K.unicapsula (26, 27). Transverse (26) and cross (27) sections through the basal part of the spore showing unequal polar capsules and four shelves. Big polar capsule contains two coils of polar filament. 28—Spore construction of M. adeli sp. nov. Host infected: M. cephalus (4–7, 14, 15, 19, 21, 23); L. aurata (1, 8–13, 20, 22, 24–27); L. ramada (2, 3, 16–18, 28). Sites: intestine (1, 8–13, 15, 19, 24–27), pyloric caeca (2, 3), scales (4, 7), gills (14), gall bladder (16, 18, 20, 21, 23), and kidney (22).
pole and occupy half or a more than a half of the spore cavity. Polar capsules of equal sizes. Suture line well expressed; sometimes slightly folded. Spore dimensions from glycerine jelly mounts were 6.19±0.29 μm (5.56–6.75) in length; 7.22±0.28 μm (6.57–7.77) in width, and 4.60±0.36 μm (3.55–5.27) in thickness (n=50). Polar capsules measured 3.07±0.32 μm (2.36–3.8)×1.81±0.22 μm (1.26–2.28). Four coiled polar filament measured 13.45±1.95 μm (12.0–17.76) in length.

**Syntype specimens.** Glass slides numbers AAK 7, 15, 19, 20, 21, 22, 23, 29, 33, 37, 44; AAG 6, 8, 13, 38, 42, 51, 63, 64, 136, 157, 148; MAE 31; 2 MAE 21, 26, 39, 56, 65; 2 MAS 3, 4, 5, 6, 7, 8, 11, 12; 3 MAE 17, 20, 49; 3 MAS 4, 7, 8, 13, 17, 32, 35; and 4 MAE 9, 10, 12, 18, 23, 24, 29, 31 were deposited in the collection of the Department of Parasitology of Institute of Biology of the Southern Seas of National Academy of Sciences of Ukraine, 2 Nakhimov Avenue, 99011, Sevastopol, Ukraine.

**Etymology.** Species is called to the honor of Adel Kovalyova, expert on Myxosporea studies, who worked long-time in the Institute of Biology of the Southern Seas (IBSS) and Fish Diseases Laboratory AtlantNIRO, Kaliningrad, Russia.

**Taxonomic summary.** The new myxosporean species differs from other representatives of the genus *Myxobolus* by morphology and spore sizes. The spore shape and/or measurements of the present species showed some similarities with Myxosporea from the Eurasia freshwater hosts: *M. improvisus* Isjumova, 1964 in. Schulman 1966; *Myxobolus latus* Schulman, 1962 and *Myxobolus artus* Achmerov, 1960. *M. adeli* sp. produces spindle-shaped plasmodia contrary to *M. improvisus* and *M. latus* with round- or oval-shaped (*M. artus*) vegetative stages. The spores of newly described...
species are comparatively smaller than the spores of all three related species. M. adeli sp. n. differs from M. improvisus also by equal sized polar capsules (Table 2).

Alataspora sp. (Table 3; Figs. 16, 17)

Type host. Thinlip mullet L. ramada (Risso, 1826)

Site of infection. Gall bladder

Locality. Mediterranean coastal waters (Ebro River Delta, Santa Pola)

Prevalence. 2.7 % (1/37) in 2004; 0.9 % (1/109) in 2005

Description. Vegetative stages presented by rounded or oval-shaped bisporous plasmodia with transparent ectoplasm and small-grained endoplasm. Spores are strongly elongated in the plane perpendicular to the sutural line. They have clearly expressed triangular part, cavity of which contains polar capsules and amoeboid germ. Elongated top parts of the valves form single wing-like appendages slightly unequal in sizes. Suture line is straight and clear. Spherical polar capsules are located close to the anterior pole and open near the suture line to one side of spore. Amoeboid germ is located under polar capsules.

Spore measurements presented in Table 3.

Taxonomic summary. Based on the spore construction, Alataspora sp. occupies intermediate position between
representatives of *Alataspora* and *Pseudalataspora* genera. It resembles *Alataspora solomoni* Yurakhno, 1988, differing from it by unequal length of valves and larger spores and polar capsules. We consider *Alataspora* sp. a *species inquirenda* that needs a precise species description after obtaining of additional data.

### Table 3 *Alataspora* sp. measurements

| Plasmodia and spores measurements | Fresh material (*n*=20) | Smears colored with Giemsa stain (*n*=22) |
|----------------------------------|-------------------------|----------------------------------------|
| Plasmodium length                | 15.65±5.58 (5.5–26.5)   | 15.02±6.38 (4.01–34.38)                |
| Plasmodium width                 | 14.7±4.89 (5.5–23.5)    | 13.78±5.5 (3.33–25.03)                 |
| Spore length                     | 8.3±0.54 (7.5–9.0)      | 9.9±1.08 (8.10–11.56)                  |
| Spore thickness                  | 24.16±3.0 (19.0–28.5)   | 24.29±3.22 (19.76–29.85)               |
| Thickness of bigger valve        | 13.8±1.58 (12.0–17.0)   | 12.8 (10.32–15.91)                     |
| Thickness of smaller valve       | 11.67±1.37 (8.5–13.0)   | 11.61 (9.44–13.94)                     |
| Polar capsule length             | 3.1±0.08 (3.0–3.3)      | 2.77±0.32 (2.2–3.21)                   |
| Polar capsule width              | 3.1±0.08 (3.0–3.3)      | 2.52±0.34 (1.78–3.11)                  |
| Number of polar filament coils   | 5                       | –                                      |
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