Gyrodactylus aff. mugili Zhukov, 1970 (Monogenoidea: Gyrodactylidae) from the gills of mullets (Mugiliformes: Mugilidae) collected from the inland waters of southern Iraq, with an evaluation of previous records of Gyrodactylus spp. on mullets in Iraq

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Abstract: Gyrodactylus aff. mugili Zhukov, 1970 (Monogenoidea: Gyrodactylidae) is recorded and described from the gill lamellae of 11 of 35 greenback mullet, Chelon subviridis (Valenciennes) (minimum prevalence 31%), from the brackish waters of the Shatt Al-Arab Estuary in southern Iraq. The gyrodactylid was also found on the gill lamellae of one of eight Speigler’s mullet, Valamugil speigleri (Bleeker), from the brackish waters of the Shatt Al-Basrah Canal (minimum prevalence 13%). Fifteen Klunzinger’s mullet, Liza klunzingeri (Day), and 13 keeled mullet, Liza carinata (Valenciennes), collected and examined from southern Iraqi waters, were apparently uninfected. The gyrodactylids from the greenback mullet and Speigler’s mullet were considered to have affinity to G. mugili Zhukov, 1970, and along with G. mugili may represent members of a species complex occurring on mullets in the Indo-Pacific Region. A single damaged gyrodactylid from the external surfaces of the Abu mullet, Liza abu (Heckel), was insufficient for species identification. Previously identified species of Gyrodactylus recorded on L. abu in Iraq by various authors were considered possible misidentifications or accidental infections.

Keywords: Gyrodactylidea, Gyrodactylus mugili, species complex, Chelon subviridis, Liza abu, Liza carinata, Liza klunzingeri, Valamugil speigleri, mullets, Asia, Shatt Al-Arab River, Shatt Al-Arab Estuary

The Mugilidae (Mugiliformes), comprising 17 genera and 72 valid species commonly called mullets or grey mullets (Eschmeyer and Fong 2013, Froese and Pauly 2013), includes mostly marine and brackish-water coastal fishes occurring in tropical and temperate seas worldwide. Mullets are euryhaline, with many species moving into freshwater from marine habitats for short periods. Only one, the Abu mullet, Liza abu (Heckel), of southwestern Asia (Iraq, Iran, Pakistan, Turkey and Syria) is restricted to fresh and brackish waters (Thomson 1997, Froese and Pauly 2013). Mullets are herbivorous and/or detritivorous fishes, feeding on algae, diatoms and small invertebrates associated with algae, and detritus obtained from bottom muds and sands (Coad 2010). In southern Iraqi waters, mullets, particularly L. abu, Klunzinger’s mullet, Liza klunzingeri (Day), and greenback mullet, Chelon subviridis (Valenciennes), are commercially fished and comprise economically important local food sources (Coad 2010).

Investigations into the polynchoinean parasites (Monogenoidea) of mullets have focused primarily on those occurring on their gill lamellae; about 50 species of Ligophorus Euzet et Suriano, 1977 (Dactylogyridea: Dactylogyridae) have been recorded from these hosts worldwide (see Dmitrieva et al. 2012, Soo and Lim 2012 and references therein), whereas the records of other dactylogyrids on mullets in Iraq and India apparently represent accidental infestations or erroneous identifications (Tripathi 1959, Abdul-Rahman 1999, Mhaisen et al. 2003a, Bannai et al. 2005).

Only five species of Gyrodactylus von Nordmann, 1832 (Polychoinea: Gyrodactylidea: Gyrodactylidae) have been described from mullets. These include Gyrodactylus zhukovi Ling, 1962 and Gyrodactylus mugili Zhukov, 1970 from so-iuy mullet, Mugil soiuy Basilewsky, now Liza haematocheila (Temminck et Schlegel), from China and the Sea of Japan, respectively; Gyrodactylus mugelus Rawson, 1973 from flathead grey mullet, Mugil cephalus Linnaeus, from off the Georgia coast of the United States; Gyrodactylus curemae Conroy et Conroy, 1985 from white mullet, Mugil curema Valenciennes, from off the coast of Venezuela; and Gyrodactylus xiamenensis Yang et Liu, 2001 from largescale mullet, Liza macrolepis
Chelon macrolepis (Smith), from Fujian Province, China (see Zhukov 1970, Rawson 1973, Conroy and Conroy 1985, Zhang et al. 2001). Four nominal species of Gyrodactylus that were originally described from other host species have been recorded as parasites of mullets in Iraq. Gyrodactylus baikalensis Bogolepova, 1950, originally described from the abysso-cottid, Limnocottus godlewskii (Dybowski) and the cotto-comephorid, Batrachocottus multiradiatus Berg (both scorpaeniformes), was reported on L. abu by Mhaisen et al. (1995), Mohammad-Ali et al. (1999) and Balasem et al. (2002). Gyrodactylus vicinus Bychowsky, 1957, originally described from Phoxinus phoxinus (Linnaeus) and Schizothorax intermedius McClelland, now Schizopyge curvifrons (Heckel) (both cypriniformes, cyprinidae), and Gyrodactylus menschikowi Gvosdev, 1950, originally described from Barbatula barbatula (Linnaeus) (Cypriniformes: Nemacheilidae), were reported from abu mullet in Iraq by Al-Nasiri et al. (2003) and Al-Zubaidy (2007), respectively. Finally, Gyrodactylus elegans von Nordmann, 1832, a catch-all taxon with Abramis brama (Linnaeus) (Cypriniformes: Cyprinidae) as its type host, has been frequently reported from Iraq on L. abu (Ali and Shaaban 1984, Ali 1985, Mhaisen et al. 1995, 2003b, Mohammad-Ali et al. 1999, Al-Awadi 2003, Al-Nasiri et al. 2003, Al Sa’adi 2007, Al-Awadi et al. 2010).

In view of the comparatively high host-specificity exhibited by species of Gyrodactylus on related host groups (Bakke et al. 1992), it is unlikely that these previously described Gyrodactylus spp. occur as natural parasites of mullets (Mugiliformes), which suggest that these records either represent misidentifications or accidental infections. Unidentified species of Gyrodactylus sp. have also been recorded on abu and greenback mullets in Iraq (Al-Salim and Jori 2000, Al-Janae’e 2010) and may be the same form recognized herein as Gyrodactylus aff. mugili Zhukov, 1970.

During surveys of polynchromeans infecting various fishes from fresh and brackish water habitats associated with the Shatt Al-Arab river and estuary in southern Iraq, specimens assignable to Gyrodactylus were collected from three of five species of mullets. Except for a single damaged gyrodactylid found on the abu mullet, the specimens from southern Iraqi waters were considered to have affinity with G. mugili. The latter gyrodactylids are described herein as G. aff. mugili based on material collected from the greenback mullet.

MATERIALS AND METHODS

Five species of mullets were examined for gyrodactylids from fresh and brackish water in southern Iraq. Mullets included the abu mullet, greenback mullet, Klunzinger’s mullet, keeled mullet, Liza carinata (Valenciennes), and Speigler’s mullet, Valamugil speigleri (Bleeker). Fishes were collected by local fishermen using gill or cast nets from various localities along the Shatt Al-Arab River and Estuary and near the dam on the Shatt Al-Basrah Canal from March 2011 to October 2012 (Fig. 1).
Fish were immediately killed with a blow to the head, after which the gill baskets were removed and placed in vials containing hot (60°C) 5% formalin (2% formaldehyde) solution. The vials were then shaken vigorously for 15–30 sec and labeled. In addition, some entire specimens of Abu and greenback mullets were placed in containers containing hot 5% formalin; containers were vigorously shaken for about two min to remove gyroductylids from the skin, after which the contents were allowed to settle, the clear liquid decanted and the sediment placed in smaller labeled containers, and along with those containing the gill arches, shipped to Idaho State University for study. Some helminths, picked from the sediments with a fine probe under low-magnification microscopy, were mounted unstained on microscope slides in Gray and Wess medium for study of sclerotized structures; other specimens were stained with Gomori’s trichrome and mounted in Canada balsam on a slide for examination of soft anatomy (Kritsky et al. 1978, Humason 1979).

Illustrations were prepared with the aid of a camera lucida or microprojector. Measurements, all in micrometres, were obtained using a calibrated filar micrometer mounted on a phase-contrast microscope and were represented by straight-line distances between extreme points. They were expressed as the mean followed by the range and number (n) of structures measured in parentheses; body length included also that of the haptor. Haptoral terminology was that of Mizelle and Kritsky (1967) and Kritsky and Mizelle (1968). Scientific and common names of fishes were those listed in FishBase (Froese and Pauly 2013) and verified in Eshmeyer (2013).

Helminth specimens were deposited in United States National Parasite Collection (USNPC), Beltsville, Maryland; the University of Nebraska State Museum, Harold W. Manter Laboratory (HWML), Lincoln, Nebraska; the Natural History Museum (NHMUK), London, United Kingdom; and the helminth collection of the Institute of Parasitology, Academy of Sciences of the Czech Republic (IPCAS), České Budějovice, Czech Republic, as indicated in the taxonomic account.

Minimum prevalence, used herein to indicate the size of the infected segment of the host population, is defined as the smallest proportion of examined hosts (mullets) infected with gyroductylids. This concept reflects the real possibility that gyroductylids might have been missed during examination of sediments obtained from individual fishes due to the difficulty in finding the small, colourless and transparent worms within the detritus. When intensities are low, as they apparently were in most of (within the city of Abu Al-Khaseeb) on 27 August 2012 (salinity 5.0 ppt) were apparently uninfected. Gills of one of eight Valamugil speigleri (minimum prevalence 13%) from the Shatt Al-Basrah Canal (19 September 2012; salinity 23.8 ppt) were infected.

Gyroductylids were not found on three V. speigleri from the Shatt Al-Arab Estuary near Fao (4 September 2012; salinity 31.1 ppt), five Liza klunzingeri from the Shatt Al-Arab River near Naher Khooz, Abu Al-Khaseeb (27 August 2012; salinity 5 ppt), five L. klunzingeri from the Shatt Al-Arab River at Ashar, the centre of Basrah (25 August 2012; salinity 2.3 ppt), five L. klunzingeri from the Shatt Al-Arab Estuary near Fao (4 September 2012; salinity 31.1 ppt), and 13 Liza carinata from the Shatt Al-Basrah Canal (29 August 2012; salinity 23.4). A single gyroductylid (USNPC 106946) was found within the skin washings of Liza abu collected on 19 September 2011 from the Shatt Al-Arab River near Seebah (salinity 2.5 ppt).

Although the original description of Gyrodactylus mugili Zhukov, 1970 is insufficient to identify the species with certainty, all gyroductylids collected during the present study, with the exception of the specimen from L. abu, were considered to have affinity to this species, based on the comparative morphology of the anchor/bar complexes of present specimens with the respective figure (Fig. 4a) in Zhukov (1970). The specimen from the external surfaces of L. abu was damaged and insufficient for identification.

Class Monogenoidea Bychowsky, 1937
Subclass Polyonchoinea Bychowsky, 1937
Order Gyroductylidea Bychowsky, 1937
Gyroductylidae van Beneden et Hess, 1863

Gyroductylus aff. mugili Zhukov, 1970 Figs. 2–7

Description (based on 33 [19 stained] specimens from Chelon subviridis; measurements in Table 1): Body proper fusiform; greatest width usually at level of uterus when containing embryo; peduncle short, tapering toward haptor.

Cephalic lobes poorly to well developed, each containing large head organ, inconspicuous spike sensilla. Cephalic glands comprising bilateral groups of unicellular glands posterolateral to pharynx; prepharyngeal cephalic glands not observed. Pharynx having two tandem subequal bulbs, pharyngeal papillae inconspicuous or oesophageus short; intestinal caeca nonconfluent, extending slightly posterior to testis, with moderately thick walls. Testes with flattened anterior margin abutting posterior margin of germarium. Proximal portion of vas deferens, seminal vesicle and prostates not observed. Male copulatory organ lying to right or left of body midline, armed with large spine and four to six (usually five) spinelets; medial spinelets smaller than lateral spinelets. Germarium subspherical, containing large oocyte surrounded by thin peripheral layer of germinal cells; ovi-
duct not observed; uterus with one or two generations of embryos (or empty); uterine pore not observed. Vitellari-um absent or replaced by up to eight apparently syncytial masses located in posterior trunk and peduncle.

Haptor subcircular. Hooks similar, extrahamular; each with uniform shank having imperceptible proximal enlargement; hooklet with long fine evenly curved point, straight shaft, globose heel, tapered toe, slanting shelf; filamentous hooklet loop about 1/2 shank length. Anchor delicate; anchor base with poorly developed folds and conspicuous knobs; superficial anchor root moderately long, tapered; anchor shaft slightly bowed; point recurved, elongate. Superficial bar lacking anterolateral rami, with slightly enlarged ends; superficial-bar shield short, tapered posteriorly, extending posteriorly about 1/3 length of anchor shaft; deep bar variably bent, simple rod with attenuated ends inserted into anchor knobs.

Type host: So-iuy mullet, Mugil soiuy Basilewsky, now Liza haematocheila (Temminck et Schlegel), Mugilidae.

Type locality: Sea of Japan.

Figs. 2–7. *Gyrodactylus aff. mugili* Zhukov, 1970 from the greenback mullet, *Chelon subviridis* (Valenciennes), from the Shatt Al-Arab Estuary in southern Iraq. Fig. 2. Whole mount (composite, ventral view). Fig. 3. Male copulatory organ. Fig. 4. Hooklet. Fig. 5. Anchor. Fig. 6. Anchor/bar complex. Fig. 7. Hook.
Ahead of print online version

**Site of infection:** Gills.

**Source of current specimens:** Greenback mullet _Chelon subviridis_ (Valenciennes), Mugilidae; Shatt Al-Arab Estuary near Fao, Al-Basrah Province, Iraq (48°50'E, 29°32'N), 31 March 2012; Speigler’s mullet, _Valamugil speigleri_ (Bleeker), Mugilidae; near the dam on the Shatt Al-Basrah canal, Iraq (47°46'E, 30°24'N), 19 September 2012.

**Specimens studied:** 33 voucher specimens from _C. subviridis_, USNPC 106948, HWML 49823, NHMUK 2013.5.15.1–5; IPCAS M – 537 (two voucher specimens retained in the collections of the junior authors); 16 voucher specimens from _V. speigleri_, USNPC 106947.

**Previous records as _G. mugili_:** _Mugil soiuy_ Basilewsky; _L. haematocheila_ and _Mugil cephalus_ Linnaeus: Strait of Kerch between the Black Sea and Sea of Azov (Miroshnichenko and Maltsev 1998a); other records from the Azov Sea and far-eastern Russia are listed in Kostadinova (2008). _Magil cephalus_ Linnaeus: Strait of Kerch between the Black Sea and Sea of Azov (Miroshnichenko and Maltsev 1998a); Azov Sea (as striped mullet) (Miroshnichenko and Maltsev 1998b).

**Remarks.** _Gyrodactylus aff. mugili_ is differentiated from the other species of _Gyrodactylus_ infecting mullets by lacking anterolateral processes on the superficial bar (anterolateral processes present in _G. mugelus_, _G. curemae_ and _G. zhukovi_) and by having delicate anchors with moderately long and tapered superficial roots (anchor base robust with a short stumpy superficial root in _G. ximenensis_).

Although morphological differences in the hook and hooklet had previously been determined to be important in differentiating species of _Gyrodactylus_ (Malmberg 1964, Mizelle and Kritsky 1967), Zhukov (1970) failed to figure or describe in detail these structures in _G. mugili_. Thus, it was not possible to definitively assign the Iraqi specimens to this species or to determine their possible status as an undescribed taxon. Iraqi specimens clearly have a close affinity to _G. mugili_ based on the morphological similarity of their anchor/bar complexes with the respective drawing presented by Zhukov (1970). Therefore, present specimens are identified herein as _G. aff. mugili_, while recognizing that they along with _G. mugili_ may represent a complex of morphologically similar species infecting mullets in the Indo-Pacific region.

Miroshnichenko and Maltsev (1998a), who reported _G. mugili_ from so-iuy mullet and the flathead grey mullet from the Azov-Black Sea Basin, provided drawings of the haptoral sclerites of the gyrodactylid, including that of the haptoral hook. Their depiction of the hooklet, while resembling that of Iraqi specimens, suggests that the structure in their specimens is slightly more robust.

It is unknown whether the gyrodactylid identified by these authors was introduced along with the so-iuy mullet

### Table 1. Measurements of _Gyrodactylus aff. mugili_ from mullets in Iraq and the Sea of Japan.

<table>
<thead>
<tr>
<th>Hosts</th>
<th>Body Length (mm)</th>
<th>Body Width (mm)</th>
<th>Haptor Length (mm)</th>
<th>Haptor Width (mm)</th>
<th>Pharynx Anterior bulb width (mm)</th>
<th>Pharynx Posterior bulb width (mm)</th>
<th>MCO Diameter (mm)</th>
<th>Testis Length (mm)</th>
<th>Testis Width (mm)</th>
<th>Germarium Diameter (mm)</th>
<th>Anchor Length (mm)</th>
<th>Anchor Superficial bar Length (mm)</th>
<th>Anchor Deep bar Length (mm)</th>
<th>Hook Length (mm)</th>
<th>Hooklet Length (mm)</th>
</tr>
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<tbody>
<tr>
<td><strong>Chelon subviridis</strong> (Iraq)</td>
<td>294 (232–350; n = 19)</td>
<td>74 (59–90; n = 18)</td>
<td>70 (56–82; n = 17)</td>
<td>69 (59–80; n = 15)</td>
<td>27 (24–31; n = 15)</td>
<td>28 (25–31; n = 15)</td>
<td>11 (10–13; n = 9)</td>
<td>46 (43–48; n = 14)</td>
<td>19 (18–20; n = 7)</td>
<td>10 (8–12; n = 5)</td>
<td>26 (24–27; n = 27)</td>
<td>5 (4–6; n = 23)</td>
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<tr>
<td><strong>Valamugil speigleri</strong> (Iraq)</td>
<td>257 (241–275; n = 6)</td>
<td>72 (58–83; n = 6)</td>
<td>58 (54–62; n = 6)</td>
<td>59 (55–63; n = 6)</td>
<td>25 (23–30; n = 6)</td>
<td>26 (24–30; n = 6)</td>
<td>11 (9–13; n = 3)</td>
<td>43 (41–44; n = 5)</td>
<td>13 (12–14; n = 3)</td>
<td>12 (9–15; n = 3)</td>
<td>19 (17–22; n = 5)</td>
<td>5 (4–6; n = 23)</td>
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<tr>
<td><strong>Liza haematocheila</strong> (Sea of Japan)</td>
<td>200–270</td>
<td>70–80</td>
<td>50–56</td>
<td>62–66</td>
<td>-</td>
<td>-</td>
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<td>53–56</td>
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<td>29–31</td>
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1Formerly _Mugil soiuy_ Basilewsky; 2measurements from Zhukov (1970); 3excluding haptor.
into the Azov-Black Sea Basin from the western Pacific or if it represents a form present in the basin prior to the fish’s introduction. Unfortunately, the type specimens of *G. mugili* have apparently been lost and probably no longer exist (P. Gerasev, personal communication). Thus, collection of *G. mugili* from so-iuy mullets from near the type locality in the western Pacific will be necessary to verify whether the form from the Azov-Black Sea Basin is *G. mugili* (*sensu stricto*), or if it represents another member of the putative species complex. Both morphological and molecular methodology will likely be necessary to define the species complex, if one actually exists on mullets within the region.

Malmberg (1970) found that water temperature, habitat (salinity levels) and host size (age) could affect the morphometrics of some of the haptoral sclerites of gyrodactylids. Similar findings were subsequently reported for these helminths by Mo et al. (1991a–c), Dávidová et al. (2005) and Olstad et al. (2009).

During the present study, gyrodactylids were collected from the brackish waters of the Al-Basrah Canal and Shatt Al-Arab Estuary in Iraq; none were obtained from the marine waters of the Arabian Gulf. Whereas minimal morphological variation occurred in specimens from the two mullet hosts, metrical differences of some structures in these gyrodactylids were noted (Table 1).

It is presently unknown whether this variation is intraspecific, resulting from the physical factors associated with the collection sites or those presented by the hosts, or if it represents species-specific features. Since fishes were not sampled from the marine environment, it is also unknown whether *G. aff. mugili* represents a fresh/brackish water form acquired by the mullets as they entered the inland waters of Iraq or if the helminths initially occurred on these host within the Arabian Gulf prior to their hosts’ migration into estuarine waters.

Finally, tolerance of *G. aff. mugili* to changes in salinity as their hosts migrate to and from the inland waters of Iraq are unknown. Additional collections and studies on gyrodactylids from mullets occurring in a variety of habitats are needed to evaluate the environmental factors under which they may survive within the region.

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