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PARASITIC COPEPODS (CRUSTACEA: COPEPODA) INFECTING MUSCLES OF A MARINE FISH (ACTINOPTERYGII: MORIDAE)—A SPECTACULAR EFFECT ON A HOST FISH AND A CASE OF SEAFOOD IDENTITY FRAUD

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Background. Automated processing of the fish caught on board a ship can potentially lead to a quality control breach. Specimens visibly infected with parasites are processed, frozen, and directed to the market. On the other hand, the removal of the body elements of taxonomic importance (e.g., fins, head, skin) opens gates to variously motivated seafood frauds. We had been alerted by local veterinary authorities about a fish consignment from the Falklands with a substantial volume of muscles with black contents.

Materials and methods. The material for the presently reported study were decapitated, finless, and gutted fish delivered to our lab by the County Veterinary Officer of Szczecin (Purchased by a local importer from a Spanish fish wholesaler). The fish were labeled as "*Pseudophycis bachus* (Forster, 1801)", and allegedly came from the Falklands. After thawing, the fish muscles were dissected, focusing on the distinctly black areas, examined following methods commonly used in parasitology, and observed under a dissecting and a compound microscope. Samples were collected also for molecular studies aiming to disclose the fish taxonomic identity. DNA barcoding gene (cytochrome c oxidase subunit I, COI) was used to perform the genetic characterization for the collected fish specimens. The degree of similarity between the new records (MT318699 and MT318700) and the other records of Moridae species in the GenBank was assessed by building COI gene phylogeny.

Results. The muscles contained large galls filled with black fluid. The fluid stained the adjacent muscles. Inside each gall, we found a single female of *Sarcotaces* sp., several "dwarf" males, eggs, and newly hatched nauplius stages. Using the molecular methods, the fish were identified as *Mora moro* (Risso, 1810).

Conclusions. A preliminary veterinary inspection of the catch on board of fishing vessels may help to avoid huge financial losses when a parasitized fish consignment is rejected by veterinary authorities on land. It is evident that the European regulation regarding fish parasites requires an urgent revision. *Mora moro* does not occur off the Falklands as declared by the wholesaler. This seafood fraud was probably motivated by the urge to conceal a catch from European waters and thus avoid exceeding national fishing quotas. Species of the genus *Sarcotaces* require a revision backed by molecular methods.

Keywords: copepod, *Sarcotaces*, endoparasite, mesoparasite, host–parasite relation, *Mora moro*, seafood fraud, fish quota violation

INTRODUCTION

The European Union (EU) is the leading trader of fisheries and aquaculture products in the world, in terms of value. The EU fish market (i.e. imports and exports) has increased over the past few years, reaching EUR 32.3 billion in 2018. Norway, China, Ecuador, and Morocco are the EU's main fish suppliers. The volume of non-EU imports remained almost stable since 2006, averaging 5.7 million tonnes per year, with the highest level of 6.3 million tonnes, recorded in 2018 (EUMOFA**).

Poland is 17th among the largest importers of fish and seafood in the world with a share of 1.6% in 2016. Import

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** *https://www.eumofa.eu*

regulations for these products are harmonized, meaning that the same rules apply in all EU countries. Imports of fishery products from non-EU countries must enter the EU via an approved Border Inspection Post under the authority of an official veterinarian in the EU Member State in question. Each consignment is subject to a systematic documentary check, identity check, and physical check. The frequency of physical checks depends on the risk profile of the product and also on the results of previous checks (Anonymous 2017b, 2019c, 2019d). These analyses may target heavy metal residues or any other contaminants such as parasites. During these random tests, shipments may still be cleared and delivered to EU customers. However, if the tests reveal any contamination, the establishment that sent the shipment in question will be put on "reinforced control status." This status is then communicated to all member states as well as to the European Commission through the Rapid Alert System. Consignments that are found not to be compliant with EU legislation shall either be destroyed or, under certain conditions, re-dispatched within 60 days (Anonymous 2019e). The head of the Veterinary Inspection in Poland is the Chief Veterinary Officer (CVO) who supervises 16 Voivodeship Veterinary Officers (VVO) and 9 Border Veterinary Officers (BVO). The CVO is based in the General Veterinary Inspectorate, while the VVOs are based in Voivodeship Veterinary Inspectorates. Border Veterinary Officers are based in Border Veterinary Inspectorates, but some of them have additional checkpoints. The lowest level of supervision constitute the County Veterinary Officers (305 in Poland) residing in County Veterinary Inspectorates. The Veterinary Inspection is obliged to supervise the safety of animal-derived foodstuffs, including production, marketing, and direct sale stages. The first line of defense are Border Veterinary Inspectorates (Anonymous 2017a), but their role within the EU trade has been largely limited.

Food fraud, while not a new phenomenon, has come under the spotlight in recent years. Fish fraud is committed when fish is deliberately placed on the market, for financial gain, with the intention of deceiving the customer. There are many different types of fish fraud that can take place at multiple points along the fish supply chain. A major report by the Oceana (Anonymous 2016a) reviewed more than 200 published studies on fish fraud from 55 countries worldwide found that, on average, 20 percent of all fish in the retail and catering sectors was mislabeled. Some of the most common forms of fish fraud involve species substitution, where a low-value species replaces a more expensive variety for economic gain, or where a high-value species is presented as a lower-value species for tax evasion purposes, mislabelling of fish to conceal the geographical origin of illegally harvested species. Combating fish fraud is a complex task for national authorities as, usually, no single government agency has the regulatory mandate to do so and no single food law or regulation directly addresses all aspects of food fraud. Seafood frauds in the EU have been monitored by RASFF (Rapid Alert System for Food and Feed) (Anonymous 2019a).

Automated processing of the fish caught on board a ship can potentially lead to a quality control breach. Specimens visibly infected with parasites are processed, frozen, and directed to the market. On the other hand, the removal of the body elements of taxonomic importance (e.g., fins, head, skin) opens gates to variously motivated seafood frauds.

Our Division of Fish Diseases, West Pomeranian University of Technology has a long tradition of cooperation with the food quality inspection and the local veterinary authorities. This cooperation dates back to the early 1970 and it provided material to many publications (e.g., Grabda 1991).

One of the very interesting cases, related to fish parasites emerged in May 2010 and has remained unpublished until now. The County Veterinary Officer [Powiatowy Lekarz Weterynarii] of Szczecin reported o problem of a fish consignment with dark stain areas of the muscles. Such signs indicated that the culprit might be a species representing parasitic Copepoda. The fish were owned by a Polish importer who declared that he purchased the whole consignment from a Spanish fish wholesaler. According to the delivery documents, the fish were "*Pseudophycis bachus*"(family Moridae) and came from the Falklands. Even though the fish were extensively processed, some of its morphological features remained and their preliminary analysis suggested that the fish might represent another species of the same family. Our task was to determine the cause of the abnormal appearance of the fish and to verify the specific identity of the host fish.

MATERIAL AND METHODS

The material for the presently reported study constituted decapitated, finless, and gutted fish (so-called pan-dressed fish) delivered to the Division of Fish Diseases (West Pomeranian University of Technology in Szczecin, Poland), by the County Veterinary Officer [Powiatowy Lekarz Weterynarii] of Szczecin. We received 29 frozen fish, selected especially for examination. All fish delivered showed gross symptoms of black-stained areas in their muscles. The selection undoubtedly required thawing of frozen fish blocks and subsequent freezing. The fish carcasses were studied for the presence of parasites responsible for the macroscopically observed pathological changes.

After thawing, the fish muscles were dissected, focusing on the distinctly black areas. The myomeres surrounding such areas were carefully removed thus exposing the galls attached to the skin. After cutting off the excess of the skin the galls were transferred to a Petri dish, and further dissected Macroscopically visible parasites were collected. The black fluid contained in the gall was, where possible, strained through a fine gaze to separate putative microscopic-size parasite stages. The organisms found were fixed and preserved in 75% ethanol and examined under a stereomicroscope and a compound microscope, using a modified "wooden-slide" method of Humes and Gooding (1964) consisting in microscopic observations of specimens hanging in a drop of lactic

acid. The morphology of the parasitic organisms was documented by photographs and drawings. The muscles adjacent to the galls were examined for possible changes in their structure and coloration.

Samples were collected also for molecular studies aiming to disclose the fish taxonomic identity. DNA isolation from two fish specimens declared as "*Pseudophycis bachus*" was performed using the High Pure PCR Template Preparation Kit (Roche Life Science, Mannheim Germany) following the manufacturer's instructions. The qualitative and quantitative assessment of the isolates was carried out by electrophoresis in 1.5% agarose gel followed by spectrophotometric measurements using the NanoDrop 2000 instrument (Thermo Scientific). For all investigated samples, PCR amplification of COI gene was amplified using FishF2_t1 and FishR2_t1 primers described in a paper published by Ivanova et al. (2007). The amplification of the selected region was conducted using the following cycles: 1 step of 5 min at 94°C followed by 35 cycles at 94°C for 30 s, 56°C for 30 s, 72°C for 60 s, and a final extension at 72°C for 10 min. The PCR reaction was conducted on Mastercycler (Eppendorf, Hamburg, Germany) using the GoTaq PCR kit (Promega), i.e., in 25 μL with 200 ng of total DNA, 0.2 μM of each primer, 2.5 mM of $MgCl_2$, 200 μM of dNTP and 1 U of GoTaq polymerase. The results of amplification were assessed by separating the PCR products analyzed on 1.5 % agarose gel. Purified PCR products were sequenced bidirectionally by means of direct Sanger sequencing by Genomed (Warsaw, Poland) using the same primers as in amplification. Sequences were assembled and aligned with Geneious v. 8 (Biomatters) to obtain consensus sequences. Ambiguous base calls were manually annotated using corresponding chromatograms, and sequence identity and similarity to reference COI sequence of *P. bachus* (Acc. No. EF609444) was determined by a BLASTn search.

RESULTS

Of the examined 29 fish specimens, preselected by the importer, only nine contained more or less intact parasites in the fish muscles. Others showed signs of infection represented by black staining of the tissues and deep voids. We collected only nine macroscopically visible parasites which translates into a single parasite per fish (Figs. 1A, 1B), although darkly stained voids suggest double (multiple?) infections (Fig. 1C) possible in this host fish. The majority of the infections were observed on the posterior part of the body. The parasites were enclosed in thinned-wall galls made of connective tissue (Fig. 1D). The drop-shaped galls fitted tightly to the body of the parasite reflecting the appearance of the parasite (Fig. 1E) with the narrower end attached to the fish skin. The galls (parasites) were oriented with their narrower end posteriorly (Fig. 1A) and each gall was connected to an opening in the fish shin, thus allowing the parasite to have access to the external environment (Fig. 1B). The fish scales were mechanically removed, but it is possible that the parasitic aperture pierced through a scale. Each gall contained a single female parasite and a black fluid (Fig. 1F) capable of staining fish tissues during the mechanical processing of the fish. The black fluid contained microscopic-sized parasite males, eggs, and larval stages.

The studied fish tissues were of bad quality (Fig. 1E), possibly because of at least two-times thawing and re-freezing. The mechanical processing of the fish contributed also to the destruction or damage of many parasites (Fig. 1C). The muscle tissues surrounding the gall/parasite did not show visible signs of pathological changes. Only the thin (2–3 mm) layer adjacent to the gall showed yellowish discolorations (Fig. 1E) (possible traces of extravasated blood) and indistinct fibrotic changes. The thin wall of the parasitic gall was clearly delimited (Fig. 1D) although firmly overgrown by the muscle fibers, without any signs of enzymatic digestion (Fig. 1E).

The parasites found were identified as representatives of the genus *Sarcotaces*. We collected a total of nine females of which four were extensively damaged or distorted. The largest female was best preserved (Fig. 2A). A total of 20 males were collected. Two of them were found in female (W5) measuring 40 in total length and as many as 18 in female (W6) not measured because of extensive damage.

Description of female of *Sarcotaces* sp. Body elongate, drop shaped. Anterior part gently rounded, posterior part distinctly narrowing towards a pointed process (Fig. 2A). Total length of female (n = 5) reaching 25–40 mm (35.8 ± 8.1 mm); total width 10–19 mm (15.6 ± 3.0 mm). Body covered with lobate, indistinctly bifurcated protrusions (Fig. 2B). Borders between somites marked by areas lacking protrusions. Protrusions well developed in anterior part, reduced in abdominal part. Dorsal "segmentation" not consistently matching with ventral one. Cephalon associated with mouth opening. Somite th II displaced in front of cephalon (terminology after Kabata 1979) Somites th III, th IV, th V, th VI, th VII relatively short, of similar length, located posterior to mouth opening. First abdominal somite (abd I) very long, resembling truncated cone of hight similar to diameter. Abrupt setoff between abd I and abd II; abd III very small, and abd IV very small in form of terminal sharp spike. Appendages reduced or not visible.

Description of male of *Sarcotaces* sp. Males (Figs. 2C, 2D, 2E) disproportionately smaller than females, differing fundamentally in their structure. Body very strongly elongate, subcylindrical, indistinctly segmented, and not covered with protrusions. Cephalothoracic appendages well developed; thoracic appendages reduced in structure and number (2 thoracopods). Total length of males (n = 11), excluding caudal rami, reaching 2.15–3.52 mm (2.56 ± 0.38 mm), total width 0.36–0.60 mm (0.47 ± 0.083 mm). Anterior part of body semitriangular in dorsal view consisting of cephalothorax, first two (pedigerous) somites of thorax (Fig. 2E), and legless trunk. Cephalothorax relatively small and round; Pedigerous part of thorax abruptly widening and having two prominent posterolateral lobes. Legless trunk cylindrical, distinctly narrower than preceding somites; gradually widening

posteriorly. Caudal rami reduced to single big seta with 2 to 4 small setules at base.

Larval stages of *Sarcotaces* sp. Black fluid surrounding the female in the gall contained eggs and newly hatched nauplii (Fig. 2F) with three pair of appendages (antennule, antenna, mandible).

Identity of the host fish. The COI sequences of the collected specimens were aligned and compared to the corresponding sequences of other Moridae publicly available in GenBank and showed the highest similarity to *Mora moro* voucher BW-1684 (Acc, no. EF609410). Comparison between the COI sequences of the collected specimens indicated on

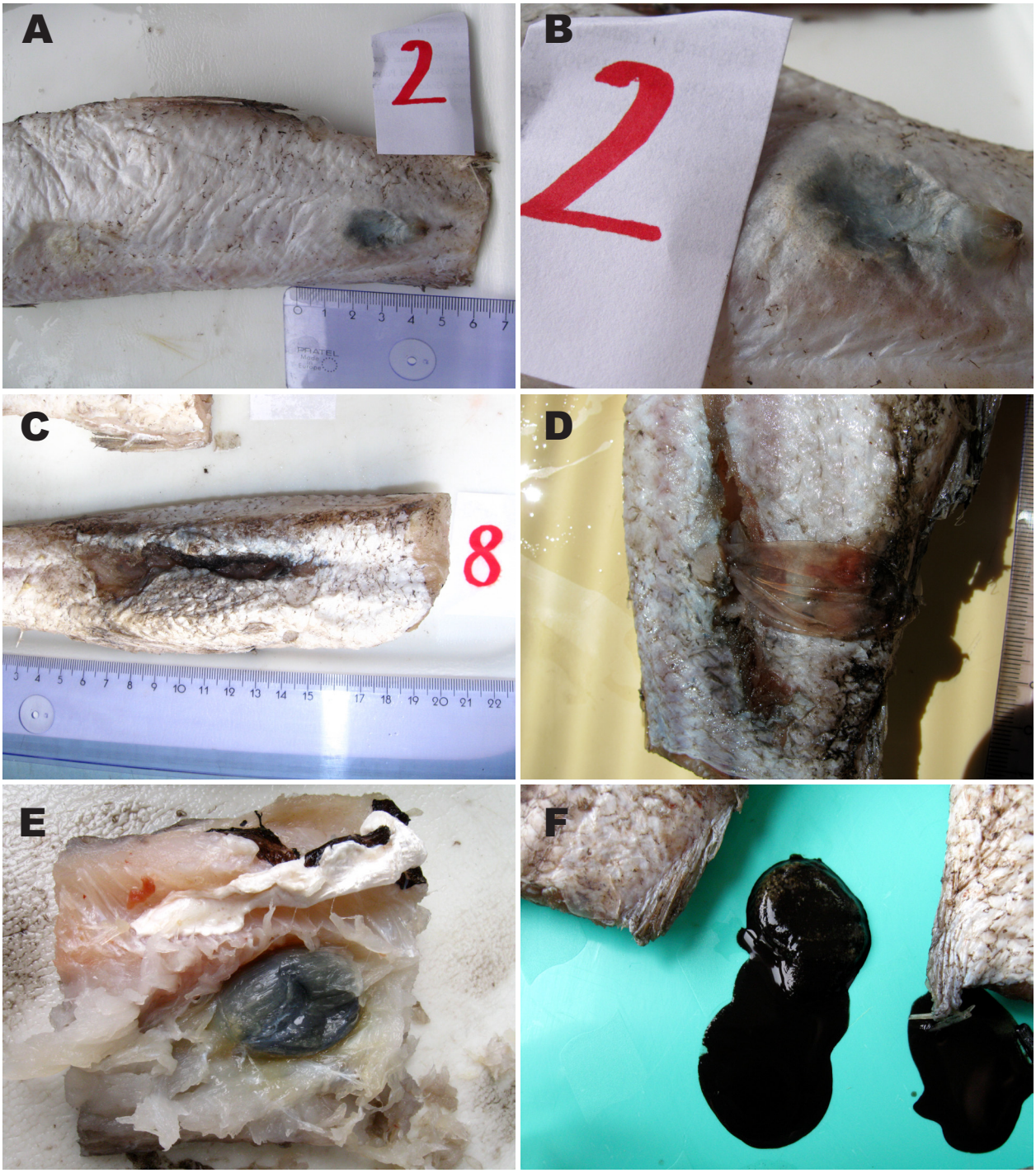

Fig. 1. Photographs documenting infection of fish (*Mora moro*) with copepod parasites (*Sarcotaces* sp.); fish carcass featuring a single *Sarcotaces* sp. in the muscles (dark area under the skin) (**A**); the same parasite magnified with an arrow pointing out to the skin aperture connecting the parasite with the external environment (**B**); dark-stained voids in the mechanically processed fish carcass, suggesting a double infection (**C**); an everted, empty, thin-walled gall of *Sarcotaces* sp. (**D**); partly removed fish muscles, exposing a dark gall of the parasite (**E**); a female of *Sarcotaces* sp. removed from the gall covered with dark fluid (Photos by Karolina Półtorak)

single nucleotide difference in the position 371 bp, therefore both sequences were deposited in the GenBank under the following voucher names and numbers: *Mora moro* voucher Pl_Mm_1 (Acc. No. MT318699) and *Mora moro* voucher Ml_Mm_2 (Acc. No. MT318700). The alignment between the deposited COI sequences and the respective sequence of *Pseudophycis bachus* (Acc. No. EF609444) showed 83% of difference. Therefore, we concluded that the host fish of the presently reported *Sarcotaces* species was *Mora moro* (Risso, 1810).

DISCUSSION

Copepods parasitic in marine fishes, representing the family Philichthyidae, are quite spectacular, not only in terms of their morphology, but also physiology, and life strategies. An interesting issue has also been the reciprocal relation between the fish and the parasite and the host pathology inflicted. The philichthyids belong to the order Poecilostmatoida. The latter are being regarded as inferior to Siphonostomatoida in relation to the evolutionary advancement of their adaptations to parasitism. The

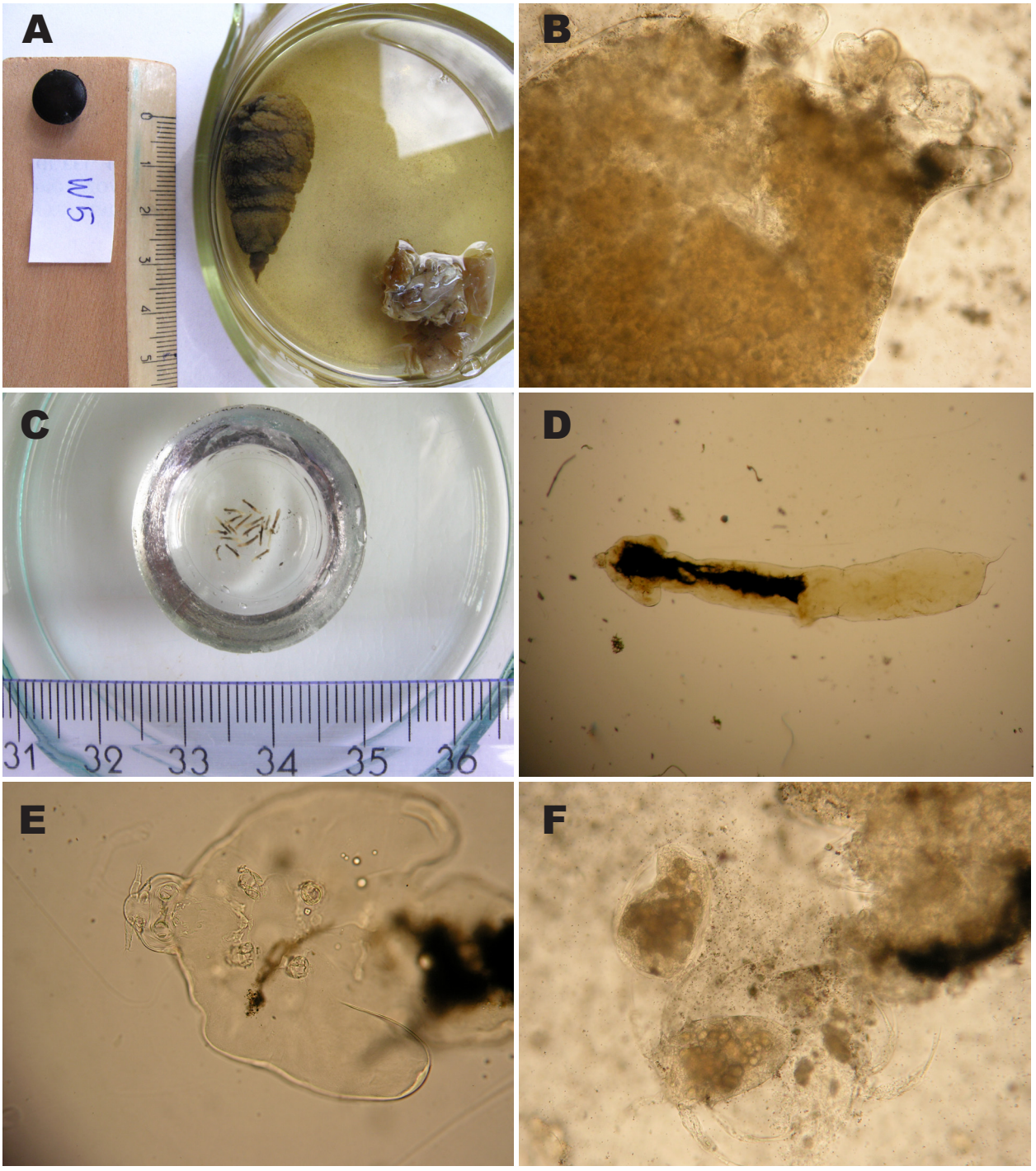

Fig. 2. Copepods (*Sarcotaces* sp.) from *Mora moro*; female on Petri dish (**A**); lobate protrusions on female surface (**B**); males (**C**); male, habitus (**D**), male cephalosome (**E**); nauplii (**F**) (Photos A and D by Karolina Półtorak; B, C, E, F by Wojciech Piasecki)

philichthyids are a notable exception because they are highly transformed and are semi-ectoparasites. Smaller species dwell in the lateral line canals. The genus *Sarcotaces* comprises the largest species of the family. They dwell in galls inside the fish muscles or even a body cavity. In the latter cases, they might even cause a parasitic fish castration (Lafferty and Kuris 2009). The gall has a minute opening linking its contents to the external environment. Amlacher (1958) illustrated the tip of a female's body protruding through such skin opening. The females are large, soft and fragile, drop-like and they float inside their chamber delimited from the host by a connective-tissue membrane lining the void in the fish muscles. The females reach 2 to 5 cm in length. Their gall (sometimes referred to as a cyst) is filled with seawater and contains also eggs and larvae of the parasite as well as "dwarf" males. Females of *Sarcotaces* are filled with a black fluid resembling ink. Mechanical processing of infected fish usually results in damage to a female and the ink spill. The ink stains the filet making it non-marketable. This fact has earned then the nickname Tintenbeutel [ink bag] among German fishermen (Amlacher 1986, Priebe 2007). *Sarcotaces* are not harmful to human fish consumers but the staining effect of their "ink" reduced the value of the affected fish landings. According to the EU regulations (Anonymous 2002, 2004) their presence disqualifies entire consignments, regardless of the infection parameters.

There are 8 nominal species belonging to the genus *Sarcotaces*: *S. arcticus* Collett, 1874; *S. verrucosus* Olsson, 1872; *S. pacificus* Komai, 1924; *S. komaii* Shiino, 1953; *S. japonicus* Izawa, 1974; *S. shiinoi* Izawa, 1974; and *S. namibiensis* Reimer, 1991.

A major revision of the family Philichthyidae was published by Delamare Deboutteville **(**1962). He published a diagramatic illustration showing comparative morphology of males of six philichthyiid genera, including *Sarcotaces*. The body segmentation interpreted by him was later accepted by subsequent authors, including Kabata (1979).

Species of the genus *Sarcotaces* are poorly known and the number of publications related to individual species is really low. *Sarcotaces verucosus* has been studied by Olsson (1872), Dollfus (1928, 1929), Heegaard (1947), Causey (1955), and Gonzales and Tanzola (2000); *S. arcticus* by Collett (1874, 1903a, 1903b), Hjort (1895), Aitken (1942), Priebe (1963), Kuitunen-Ekbaum (1949), Amlacher (1958), Berland (1970), Sekerak (1970), Avdeev and Avdeev (1975), Sekerak and Arai (1977), Moser et al. (1985), Kazačenko (1986), Kabata (1988), Stanley and Kronlund 2005); *S. pacificus* by Komai (1924), Ezpeleta Herce (1974), and Izawa (1974); *S. komaii* by Shiino (1953), Izawa (1973, 1974), Avdeev and Avdeev (1975), Kazačenko (2015). Three species, namely *S. japonicus*, *S. shiinoi*, and *S. namibiensis* were reported and studied only by their original descriptors (Izawa 1974, Reimer 1991). Many authors, dealing with *Sarcotaces*, did not even attempt to identify their finding to the species level (Table 1). Only a few such works were illustrated (Matsubara and Asano 1943, Moser 1977, Bullock et al 1986, Momoyama and Tensha 2006, Osman et al. 2014, Nagasawa et al. 2015). Some of those papers illustrate nicely the nature of fish infection (Nagasawa et al. 2015) while others document details of morphology (e.g., clusters of eggs associated with the gall wall; Osman et al. 2014), or the male appearance (Momoyama and Tensha 2006). There is a number of secondary sources mentioning *Sarcotaces* species (Ehrenbaum 1936, Amlacher 1986, González and Acuña 1998, Gordeev et al. 2017, Kietzmann et al. 1969, Love et al. 1984, Luque et al. 2008, Moles 1982, Möller and Anders 1986, Paschoal et al. 2016, Priebe 2007, Varela and Lalana 2015, Zubchenko 1987) and they are also important because of some additional data and/or remarks.

The host fishes of *S. verucosus* represented Gadiformes, Lophiiformes, Perciformes, and Scorpaeniformes. Those infected by *S. arcticus* represented Gadiformes and Scorpaeniformes. Those hosting *S. komaii* belonged to Scorpaeniformes and Gadiformes, while those associated with *S. pacificus*—to Lophiiformes and Perciformes. The three rarely encountered species namely *S. japonicus*, *S. shiinoi*, and *S. namibiensis* were found in fishes representing Anguilliformes, and Ophidiiformes, respectively.

The relative "rarity" of *Sarcotaces* findings may suggest a narrow specificity of its species. Some records were based on female morphology only and therefore are less reliable because females within the genus are quite similar, despite their variability in size and other features. It is therefore possible that "*S. arcticus*" found in the Pacific in Scorpaeniformes fishes, may represent a species which is different from Atlantic *S. arcticus* infecting gadiform fishes. We have similar concerns about *S. verucosus*. The majority of available records are from the Atlantic and represent Lophiiformes and Perciformes. It is evident that both redescriptions of the male (Heegaard 1947, Gonzales and Tanzola 2000) represent different species. The male found off Japan, depicted by Heegaard (1947), has distinct posterolateral lobes of the pedigerous thorax, whereas the male from Argentina, illustrated by Gonzales and Tanzola (2000), does not have such lobes. Moreover, the posteriorly tapering female illustrated by Gonzales and Tanzola (2000) distinctly differs in shape from the oval female of *S. verucosus* depicted by Olsson (1872) and Dollfus (1928).

Despite numerous records of *S. arcticus* only in two cases the male has been described and illustrated (Kuitunen-Ekbaum 1949, Kabata 1988). Both images were based on species of the genus Sebastes captured in British Columbia. Surprisingly, the male photographed by Kuitunen-Ekbaum (1949) differs from all other *Sarcotaces* males in having two (instead of one) paired major setae of the caudal rami.

As for the host specificity, the reasoning of Moser et al. (1985) goes, however, in the quite opposite direction. After extensive morphological studies, he concluded that *S. komaii* and *S. arcticus* may be junior synonyms *S. verucossus*. Also, Heegaard (1947), suggested that *S. verucossus*, *S. arcticus*, and *S. pacificus* might represent the same species.

Of all know *Sarcotaces* species only *S. komaii* has been reported from a fish representing the family Moridae,

Table 1

A checklist of the available records of *Sarcotaces* species

Species	Locality	Host fish (original)	Fish valid name	Fish Family	Order	Reference
S. verucosus	St. Barthelemy, Caribbean		*Acanthurus* sp.	Acanthuridae	Perciformes	Olsson 1872
S. verucosus	Martinique, Caribbean	„*Iridio radiatus*"	*Halichoeres radiatus* (Linnaeus, 1758)	Labridae	Perciformes	Dollfus 1928
S. verucosus	Martinique, Caribbean	„*Iridio radiatus*"	*Halichoeres radiatus* (Linnaeus, 1758)	Labridae	Perciformes	Dollfus 1929
S. verucosus	Pacific, Japan		*Antennarius* sp.	Antennariidae	Lophiiformes	Heegaard 1947
S. verucosus	Gulf of Mexico	"*Cariburus zaniophorus*"	*Coryphaenoides zaniophorus* (Vaillant, 1888)	Macrouridae	Gadiformes	Causey 1955
S. verucosus	Pascagoula, MO, USA		*Prionotus* sp.	Triglidae	Scorpaeniformes	Causey 1955
S. verucosus	San Matías Gulf, Argentina		*Pseudopercis semifasciata* (Cuvier, 1829)	Pinguipedidae	Perciformes	Gonzales and Tanzola 2000
S. arcticus	Øksfjord, Finmark, Norway	"*Molva abyssorum*"	*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Collett 1874
S. arcticus	Collett material	"*Molva abyssorum*"	*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Hjort 1895
S. arcticus	Andenæs, Vesteraalen, Norway		*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Collett 1903a
S. arcticus	Andenæs, Vesteraalen, Norway		*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Collett 1903a
S. arcticus	Aberdeen, Scotland	"*Molva byrkelange*"	*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Aitken 1942
S. arcticus	Berlin (client complaint)	"*Molva byrkelange*""	*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Amlacher 1958
S. arcticus	Iceland	"*Molva byrkelange*"	*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Priebe 1963
S. arcticus	British Columbia		*Sebastes ruberrimus* (Cramer, 1895)	Sebastidae	Scorpaeniformes	Kuitunen-Ekbaum 1949
S. arcticus	Norway, Bergen	"*Molva byrkelange*"	*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Berland 1970
S. arcticus	British Columbia		*Sebastes alutus* (Gilbert, 1890)	Sebastidae	Scorpaeniformes	Sekerak 1970
S. arcticus	Vancouver, Oregon		*Sebastes alutus* (Gilbert, 1890)	Sebastidae	Scorpaeniformes	Avdeev and Avdeev 1975
S. arcticus	Gulf of Alaska		*Sebastes flavidus* (Ayres, 1862)	Sebastidae	Scorpaeniformes	Avdeev and Avdeev 1975
S. arcticus	British Columbia		*Sebastes alutus* (Gilbert, 1890)	Sebastidae	Scorpaeniformes	Sekerak and Arai 1977
S. arcticus	British Columbia		*Sebastes ruberrimus* (Cramer, 1895)	Sebastidae	Scorpaeniformes	Sekerak and Arai 1977
S. arcticus	British Columbia		*Sebastes aleutianus* (Jordan et Evermann, 1898)	Sebastidae	Scorpaeniformes	Sekerak and Arai 1977
S. arcticus	British Columbia		*Sebastes brevispinis* (Bean, 1884)	Sebastidae	Scorpaeniformes	Sekerak and Arai 1977
S. arcticus	Alaska		*Sebastes ciliatus* (Tilesius, 1813)	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	California		*Sebastes auriculatus* Girard, 1854	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	California		*Sebastes entomelas* (Jordan et Gilbert, 1880)	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	California		*Sebastes flavidus* (Ayres, 1862)	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	California		*Sebastes melanops* Girard, 1856	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	California		*Sebastes rubrivinctus* (Jordan et Gilbert, 1880)	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	California		*Sebastes semicinctus* (Gilbert, 1897)	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	California		*Sebastes serranoides* (Eigenmann et Eigenmann, 1890)	Sebastidae	Scorpaeniformes	Moser et al. 1985
S. arcticus	Norway		*Molva dypterygia* (Pennant, 1784)	Lotidae	Gadiformes	Moser et al. 1985
S. arcticus	NW Pacific		*Sebastes alutus* (Gilbert, 1890)	Sebastidae	Scorpaeniformes	Kazačenko 1986
S. arcticus	NW Pacific		*Sebastes flavidus*	Sebastidae	Scorpaeniformes	Kazačenko 1986

Table continues on next page.

Table 1 cont.

Species	Locality	Host fish (original)	Fish valid name	Fish Family	Order	Reference
S. arcticus	British Columbia		*Sebastes aleutianus* (Jordan et Evermann, 1898)	Sebastidae	Scorpaeniformes	Kabata 1988
S. arcticus	British Columbia		*Sebastes alutus* (Gilbert, 1890)	Sebastidae	Scorpaeniformes	Kabata 1988
S. arcticus	British Columbia		*Sebastes brevispinis* (Bean, 1884)	Sebastidae	Scorpaeniformes	Kabata 1988
S. arcticus	British Columbia		*Sebastes ruberrimus* (Cramer, 1895)	Sebastidae	Scorpaeniformes	Kabata 1988
S. arcticus	British Columbia		*Sebastes brevispinis* (Bean, 1884)	Sebastidae	Scorpaeniformes	Stanley and Kronlund 2005
S. pacificus	Tanabe Bay, Japan	"*Antennarius tridens*"	*Antennarius striatus* (Shaw, 1794)	Antennariidae	Lophiiformes	Komai 1923
S. pacificus	Cuba		*Sparisoma rubripinne* (Valenciennes, 1840)	Scaridae	Perciformes	Ezpeleta Herce 1974
S. pacificus	Tanabe Bay, Japan	"*Antennarius tridens*"	*Antennarius striatus* (Shaw, 1794)	Antennariidae	Lophiiformes	Izawa 1974
S. komaii	Tosa Bay, Japan	"*Peristedion amiscus*"	*Scalicus hians* (Gilbert et Cramer 1897)	Platycephaloidei	Scorpaeniformes	Shiino 1953
S. komaii	Tanabe Bay, Japan	"*Antennarius tridens*"	*Antennarius striatus* (Shaw, 1794)	Antennariidae	Lophiiformes	Izawa 1973
S. komaii	Kumano Sea	"*Peristedion amiscus*"	*Scalicus hians* (Gilbert et Cramer, 1897)	Platycephaloidei	Scorpaeniformes	Izawa 1974
S. komaii	Pacific coasts of Japan		*Antimora rostrata* (Günther, 1878)	Moridae	Gadiformes	Avdeev and Avdeev 1975
S. komaii	Kuril Islands, Pacific		*Antimora rostrata* (Günther, 1878)	Moridae	Gadiformes	Kazačenko 2015
S. japonicus	Tanabe Bay, Japan		*Gymnothorax kidako* (Temminck et Schlegel, 1846)	Muraenidae	Anguilliformes	Izawa 1974
S. shiinoi	Kumano Sea	"*Promyllantor nezumi*"	*Acromycter nezumi* (Asano, 1958)	Congridae	Anguilliformes	Izawa 1974
S. namibiensis	Namibian coast		*Selachophidium guentheri* Gilchrist, 1903	Ophidiidae	Ophidiiformes	Reimer 1991
Sarcotaces sp.	Japan		*Antimora microlepis* Bean, 1890	Moridae	Gadiformes	Matsubara and Asano 1943
Sarcotaces sp.	Oregon coast		*Sebastes alutus* (Gilbert, 1890)	Sebastidae	Scorpaeniformes	Liston et al. 1960
Sarcotaces sp.	British Columbia		*Sebastes ruberrimus* (Cramer, 1895)	Sebastidae	Scorpaeniformes	Kabata 1970
Sarcotaces sp.	Japan		*Semicossyphus reticulatus* (Valenciennes, 1839)	Labridae	Perciformes	Kabata 1970
Sarcotaces sp.	Chatham Rise, New Zealand	"*Mora dannevigi*"	*Mora moro* (Risso, 1810)	Moridae	Gadiformes	Avdeev and Avdeev 1975
Sarcotaces sp.	Hawaii		Moridae gen. sp.	Moridae	Gadiformes	Avdeev and Avdeev 1975
Sarcotaces sp.	British Columbia	"ocean perch"	*Sebastes alutus* (Gilbert, 1890) ?	Sebastidae	Scorpaeniformes	Hoskins and Hulstein 1977
Sarcotaces sp.	Pacific, off El Salvador		*Physiculus rastrelliger* Gilbert, 1890	Moridae	Gadiformes	Moser 1977
Sarcotaces sp.	SW Indian Ocean		*Malacocephalus laevis* (Lowe, 1843)	Macrouridae	Gadiformes	Tkachuk 1980 (after Reimer 1991)
Sarcotaces sp.	British west coast		*Lepidion eques* (Günther, 1887)	Moridae	Gadiformes	Bullock et al. 1986
Sarcotaces sp.	British west coast		*Coelorinchus occa* (Goode et Bean, 1885)	Macrouridae	Gadiformes	Bullock et al. 1986
Sarcotaces sp.	S Australia		*Mora moro* (Risso, 1810)	Moridae	Gadiformes	West 1992
Sarcotaces sp.	Great Barrier Reef	"serranids"	Serranidae gen sp.	Serranidae	Perciformes	West 1992
Sarcotaces sp.	Yamaguchi Prefecture, Japan		*Saurida elongata* (Temminck et Schlegel, 1846)	Synodontidae	Aulopiformes	Momoyama and Tensha 2006
Sarcotaces sp.	Persian Gulf, Saudi Arabia		*Epinephelus chlorostigma* (Valenciennes, 1828)	Serranidae	Perciformes	Osman et al. 2014
Sarcotaces sp.	Ryukyu Islands		*Epinephelus fasciatus* (Forsskål, 1775)	Serranidae	Perciformes	Nagasawa et al. 2015
Sarcotaces sp.	NW Persian Gulf		*Epinephelus tauvina* (Forsskål, 1775)	Serranidae	Perciformes	Essa 2017
Sarcotaces sp.	NW Atlantic		*Antimora rostrata* (Günther, 1878)	Moridae	Gadiformes	Gordeev et al. 2019

namely *Antimora rostrata* (Günther, 1878). At least six papers provide a record of *Sarcotaces* sp. from Moridae fishes (Matsubara and Asano 1943, Avdeev and Avdeev 1975, Moser 1977, Bullock et al. 1986, Kazačenko 2015, Gordeev et al. 2019). Only Avdeev and Avdeev (1975) found "*Sarcotaces* sp. I" from *Mora moro* (Risso, 1810), which is the same host fish as described in this paper. They found a single female in a fish captured on the Chatham Rise, off New Zealand. Unfortunately, no description nor illustration was provided. It is worth to mention that West (1992) describing 11 new *Colobomatus* species of the family Philichthyidae stated that "Some members of the family have gained notoriety by becoming commercially important, for example, members of the genus *Sarcotaces* Olsson, 1872, are the "iodine worms" of the Barrier Reef serranids and southern Australian ribaldo *Mora moro* Risso." Despite our determination, we were not able to find another source confirming the above statement. Consequently, the presently reported finding constitutes the first illustrated description of *Sarcotaces* sp. from *Mora moro*.

As reported by many authors *Sarcotaces* females may distinctly differ in size, therefore their measurements are not a reliable tool for discrimination of species. Females grow substantially throughout their lives and therefore female dimensions of many species overlap. Their structure is also quite simplified and uniform. Typical copepod body parts are not available for examination. The body segmentation is deceptive and the size and distribution of small processes covering the body show individual variability within a species. Reimer (1991), provided a tabularized size comparison of males of *S. arcticus*, *S. pacificus*, *S. komaii*, *S. japonicus*, *S. shiinoi*, and *S. namibiensis*. It is evident that the male dimensions in the presently described *Sarcotaces* species distinctly differ from its known congeners. Its detailed description will be presented in a separate paper.

A preliminary veterinary inspection of the catch on board of fishing vessels may help to avoid significant financial losses when a parasitized fish consignment is rejected by veterinary authorities on land. It is evident that European regulation regarding fish parasites requires urgent revision. *Mora moro* does not occur off the Falklands as declared by the wholesaler. More specifically, no landings of this species have been recorded on the Falklands (Anonymous 2011, 2019b). In Europe, *Mora moro* is "taken as bycatch in mixed-species demersal trawl fisheries in Subareas 6, 7, and 12 and to a lesser extent, 2, 4, and 5" (Anonymous 2016b). Small bycatch amounts are reported from New Zealand*.

Reporting a fish consignment allegedly originating from the Falklands seems to be particularly convenient for seafood fraudsters. According to EU regulations (Anonymous 1998), fish consignments from the Falkland Islands do not need to be subjected to veterinary border checks at EU borders.

The presently reported seafood fraud was probably motivated by the urge to conceal a catch from European waters and thus avoid exceeding national fishing quotas. Another explanation might be an unreported catch from New Zealand or Australian Waters. Fraudulent practices apart from economic gain can be also driven by consumers searching for low-cost food, economically valuable species becoming a limited resource with increased demand, numerous visually similar species available in the seafood supply chain (Piñeiro et al. 2001, Rehbein 2008, Fox et al. 2018). The development of molecular techniques, especially DNA barcoding, allows to identify species without morphologically deterministic traits and discover possible cases of mislabeling (Bénard-Capelle et al. 2015). Such a technique relies on the amplification of marker genes, like COI used in our study, and comparing sequences to a high-quality reference database is of utmost importance (Deconinck et al. 2020). In the presently reported study, we proved the applicability of the DNA barcoding as the mislabelling attempt of *Mora moro* with *Pseudophycis bachus* was successfully confirmed.

Molecular identification of species serves as an auxiliary tool available for veterinary authorities or fish importers since correct information is critical both to assist consumers to make informed choices, increase transparency and safety in the seafood industry, as well protect the private sector from being deceived (deliberately or unknowingly) by various players along the supply chain (Bénard-Capelle et al. 2015).

In the presently described case of fraud, we can clearly see, that species identification of raw or processed food is a major issue in food inspection activity, species identification is also important in order to prevent the commercialization of species for which a conservation policy does exist (Civera 2003). It also helps to avoid illegal, unreported, and unregulated fishing.

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