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Trypanorhynch cestodes of teleost fish from the Persian Gulf, Iran

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Abstract

A total of 299 fish belonging to ten teleost species were studied in Iranian waters at the north-eastern coast of the Persian Gulf for larval trypanorhynch cestode infection. The following trypanorhynch species were identified: *Callitetrarhynchus gracilis* Pintner, 1931, *Pseudogilquinia thomasi* (Palm, 2000), *Pterobothrium lesteri* Campbell and Beveridge, 1996 and *Pseudolacistorhynchus shipleyi* (Southwell, 1929). The most abundant parasite was *C. gracilis* which was isolated from seven teleost species. The highest prevalence (62.9%) and dominance (0.98) were demonstrated for *P. thomasi* with a maximum intensity of 22 in Indian halibut *Psettodes erumei*. Collections of *P. lesteri* and *P. shipleyi* from the Persian Gulf represent new locality records, thus extending the known range of distribution for both species. Four new host records are established. The recorded combination of trypanorhynch species and the established host range correspond to other regions, such as off the Brazilian coast. In terms of species distribution, the north-western part of the Indian Ocean, together with the Gulf of Bengal and the Indonesian archipelago, share the same species, resulting from connected water bodies. All trypanorhynch species were isolated from the body cavity, except for *P. thomasi* which was recorded from the musculature of *P. erumei*. Relatively high intensities of infection in *P. erumei* may be of public health concern in the region, necessitating the consumption of well-cooked fish products.

Introduction

Fish parasites can have a negative impact on the commercial fisheries industry (Mehl, 1970; Grabda, 1977; Palm & Overstreet, 2000a). Although only a few cases of accidental human infections by trypanorhynchs have been reported (Palm, 2004), these worms may cause allergic reactions (Pelayo *et al.*, 2009). As a consequence of the highly developed large-scale fishing industry in the northern part of the Persian Gulf (Taghavi Motlagh *et al.*, 2006), thorough studies on the marine fish parasite fauna are of major importance for the region.

Trypanorhynch cestodes mature in elasmobranchs and mainly use teleost fishes as intermediate or paratenic hosts (e.g. Palm, 1997, 2000). Because of the possibility of identifying adults as well as their larval stages based on the oncotaxy of unique hook arrangements along tentacles (Campbell & Beveridge, 1994; Palm, 2004), these marine tapeworms have been considered an interesting group for taxonomic and ecological investigations (Palm & Klimpel, 2007). Of special interest is information concerning the host specificity within the taxon (Palm & Caira, 2008), providing better insight into the zoogeographical species distribution (Jakob & Palm, 2006; Palm *et al.*, 2007, 2009). Extensive fish parasitological surveys on the trypanorhynch cestode fauna in the Indian Ocean have been carried out by Palm (2000, 2004) and Palm & Overstreet (2000b) off the Indonesian coast and by Southwell (1929, 1930) off Ceylon. These authors revealed a species-rich fauna, suggesting that the former region, especially, is one of the centres of trypanorhynch species

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distribution. An observed level of low host specificity (Palm & Caira, 2008) questions how far these species extend into the western or north-western part of the Indian Ocean.

The Persian Gulf is a semi-closed water body that is connected to the Gulf of Oman through the narrow Hormuz Strait. The Gulf of Oman is the most north-westerly part of the Indian Ocean that opens into the Arabian Sea. Studies on the trypanorhynch fauna of fishes from the Persian Gulf are non-comprehensive (Mirzayans, 1970; Tirgari *et al.*, 1975; Ghiasi, 1988; El-Naffar *et al.*, 1992; Saif *et al.*, 1994; Sheini mandani, 1994; Sazandegi, 1996; Kardousha, 1999; Hassan *et al.*, 2002; Peighan *et al.*, 2004; Haseli, 2005), and focused on the most eastern region. Most recently, Haseli *et al.* (2010) studied elasmobranchs along the Iranian coast of the Persian Gulf and identified 22 taxa. These studies demonstrate that trypanorhynch cestodes are common fish parasites in the Persian Gulf, corresponding with a diverse fish fauna in the region (Blegvad & Lopenthin, 1944; Kuronuma & Abe, 1972; Randall *et al.*, 1978; Fischer & Bianchi, 1984; Kuronuma & Abe, 1986; Assadi & Dehghani, 1997; Carpenter *et al.*, 1997).

The purpose of the present study is an examination of the trypanorhynch fauna of ten commercially important teleosts from the Iranian coast of the Persian Gulf. In combination with a study of trypanorhynch cestodes from elasmobranchs from the same region (Haseli *et al.*, 2010), the present investigation compiles the known trypanorhynch fauna from the region. New host and locality records extend the known range of distribution for trypanorhynchs formerly known from the eastern part of the Indian Ocean into the Persian Gulf. For the first time, the dominance index was used in order to evaluate the infection pattern, and the Sorenson qualitative and quantitative indices to evaluate the similarity of trypanorhynch infections. To date, none of these ecological metrics have been applied to analyse the trypanorhynch infection pattern within teleost intermediate hosts.

Materials and methods

Collection and examination of fish

A total of 299 fish, comprising *Psettodes erumei* ($N = 35$, Psettodidae); Silver sillago, *Sillago sihama* ($N = 35$, Sillaginidae); Indian mackerel, *Rastrelliger kanagurta* ($N = 35$, Scombridae); Tigertooth croaker, *Otolithes ruber* ($N = 35$, Sciaenidae); Greater lizardfish, *Saurida tumbil* ($N = 35$, Synodontidae); Whitefin wolf-herring, *Chirocentrus nudus* ($N = 35$, Chirocentridae); John's snapper, *Lutjanus johnii* ($N = 35$, Lutjanidae); Spangled emperor, *Lethrinus nebulosus* ($N = 15$, Lethrinidae); Yellowfin seabream, *Acanthopagrus latus* ($N = 35$, Sparidae) and Hound needlefish, *Tylosurus crocodilus crocodilus* ($N = 4$, Belonidae) were bought in the fish market of Bandar Abbas, on the north-eastern coast of the Persian Gulf, Iran (27°11′N, 56°16′E) in April 2008. Identification was carried out according to published keys for the Persian Gulf (Assadi & Dehghani, 1997; Carpenter *et al.*, 1997). Following biometry (table 1), the fish were examined macroscopically with the help of a stereo-microscope under 6.3 × magnification for larval trypanorhynch cestodes in the body cavity, the viscera and the musculature. Encapsulated trypanorhynch larvae were freed from the blastocyst and treated according to Palm (2004). The worms were fixed in 70% ethanol and stained in acetic carmine, dehydrated in an ethanol series, cleared in methyl salicylate and mounted on to slides in Canada balsam. Trypanorhynch species identification followed Palm (2004).

Data analyses

Data analyses of the parasites and hosts were done using SPSS Package, version 13 (SPSS Inc., Chicago, Illinois, USA). According to Magurran (1988), the dominance index of the most dominant parasite species in each host (dominance index = number of individuals of the most abundant species/total number of individuals in the community) and the Sorenson qualitative (C_S = twice the number of species found in common/the total number of species that are present in two communities) and quantitative (C_N = twice the sum of the lower of the two abundances for the recorded species/the total number of individuals that are present in two communities) indices were calculated. Unlike the Sorenson qualitative index, which counts all recorded species equally irrespective of whether they are abundant or rare, the Sorenson quantitative index takes into account abundances of respective species. Thus, a better idea of the trypanorhynch cestode infection pattern can be presented by using both similarity indices. Prevalence, mean abundance, intensity and mean intensity were calculated according to Bush *et al.* (1997). The specificity index (H_S) of Caira *et al.* (2003) was used to assess host

Table 1. Number, total length and sex of examined teleost species.

Family	Fish species	Number	Total length (cm)	Sex (male: female)
Psettodidae	*Psettodes erumei*	35	34–44	24:11
Sillaginidae	*Sillago sihama*	35	16–26	7:28
Scombridae	*Rastrelliger kanagurta*	35	17.5–22	11:24
Sciaenidae	*Otolithes ruber*	35	30–41	9:26
Synodontidae	*Saurida tumbil*	35	24–51	0:35
Chirocentridae	*Chirocentrus nudus*	35	29–50	3:32
Lutjanidae	*Lutjanus johnii*	35	29–50	18:17
Lethrinidae	*Lethrinus nebulosus*	15	37.5–54	10:5
Sparidae	*Acanthopagrus latus*	35	22–34	12:23
Belonidae	*Tylosurus crocodilus crocodilus*	4	93–111	0:4

Table 2. Prevalence, intensity, mean intensity, mean abundance and infection site of trypanorhynch cestodes from ten teleost species from the Persian Gulf. New host records are marked by an asterisk after prevalence values. H_S according to Caira *et al.* (2003).

Parasite species	Host species	Prevalence (%)	Intensity	Mean intensity (± SE)	Mean abundance (± SE)
Family Lacistorhynchidae Guiart, 1927					
Callitetrarhynchus gracilis	*Psettodes erumei*	5.7	1	1 ± 0	0.06 ± 0.04
$H_S = 8.2624$	*Otolithes ruber*	5.7	1	1 ± 0	0.06 ± 0.04
	Saurida tumbil	14.3	1–9	3.6 ± 1.44	0.52 ± 0.28
	Chirocentrus nudus	28.6*	1–4	2 ± 0.33	0.57 ± 0.18
	Lutjanus johnii	8.6	1–3	2 ± 0.58	0.17 ± 0.10
	Lethrinus nebulosus	60	1–12	4.22 ± 1.14	2.53 ± 0.87
	Tylosurus crocodilus crocodilus	25*	4	4	1 ± 1
Pseudogilquinia thomasi $H_S = 0.00$	*Psettodes erumei*†	62.9	1–22	5.86 ± 1.20	3.68 ± 0.89
Pseudolacistorhynchus shipleyi $H_S = 0.00$	*Lethrinus nebulosus*	6.7*	1	1	0.07 ± 0.07
Family Pterobothriidae Pintner, 1931					
Pterobothrium lesteri $H_S = 0.00$	*Otolithes ruber*	25.7*	1–2	1.11 ± 0.11	0.28 ± 0.09

† All trypanorhynch species were isolated from the body cavity, except for *P. thomasi* which was recorded from the musculature of *P. erumei*.

specificity. Voucher specimens have been deposited in the ZUTC, collection of the Zoological Museum, University of Tehran, Tehran, Iran (ZUTC Platy 1223–5, *Callitetrarhynchus gracilis*; ZUTC Platy 1214–7, *Pseudogilquinia thomasi*; ZUTC Platy 1218–22, *Pterobothrium lesteri*; ZUTC Platy 1226, *Pseudolacistorhynchus shipleyi*) and the Museum Berlin, Germany (ZMB).

Results

Identification of cestodes and levels of infection

Four species of trypanorhynch cestodes, *Callitetrarhynchus gracilis*, *Pseudogilquinia thomasi*, *Pseudolacistorhynchus shipleyi* and *Pterobothrium lesteri*, were found in 7 out of 10 studied fish species. *Pterobothrium lesteri* and *P. shipleyi* represent new locality records from the Persian Gulf, and four new host records are established (table 2). All trypanorhynch species were isolated from the body cavity, except for *P. thomasi* which was recorded from the musculature of *Psettodes erumei*.

The most common parasite was *C. gracilis*, recovered from seven different teleost species. The highest prevalence (62.9%) was seen for *P. thomasi* with a maximum intensity of 22 in *P. erumei*. The Kolmogorov–Smirnov test demonstrated that the parasite infection was not normally distributed; therefore non-parametric tests, Mann–Whitney test (*U*) and Kruskal–Wallis test, were applied to determine whether significant differences in mean abundances of parasites exist. Prevalence, intensity, mean intensity and mean abundance of the trypanorhynch cestodes from ten teleost species from the Persian Gulf are given in table 2.

Statistical analyses revealed that the prevalence and mean abundance of *C. gracilis* in *C. nudus* were significantly higher than in *P. erumei* ($\chi^2 = 6.437$, $P = 0.011$, $U = 466.50$, $P = 0.009$), *O. ruber* ($\chi^2 = 6.437$, $P = 0.011$, $U = 466.50$, $P = 0.09$) and *Lutjanus johnii* ($\chi^2 = 4.629$, $P = 0.031$, $U = 490.50$, $P = 0.035$). Prevalence and mean abundance of *C. gracilis* in *L. nebulosus* were significantly higher than in *P. erumei* ($\chi^2 = 18.032$, $P < 0.005$, $U = 112$, $P < 0.005$), *O. ruber* ($\chi^2 = 18.032$, $P < 0.005$, $U = 112$, $P < 0.005$), *S. tumbil* ($\chi^2 = 10.884$, $P = 0.001$, $U = 139$, $P = 0.001$), *C. nudus* ($\chi^2 = 4.402$, $P = 0.036$, $U = 159$, $P = 0.012$) and *L. johnii* ($\chi^2 = 15.226$, $P < 0.005$, $U = 121.50$, $P < 0.005$).

Cestode species richness

The species richness and dominance indices are summarized in table 3. Apart from *P. erumei*, *O. ruber* and *L. nebulosus*, which had a species richness of two parasite species, this value was 1 for other infected hosts. The Sorenson qualitative similarity index showed the highest value (1) for all inter-specific comparisons of hosts that were infested with *C. gracilis*. Values were comparatively intermediate between other infested hosts. Among inter-specific comparisons of hosts in which qualitative

Table 3. Species richness and dominance index of trypanorhynch species in ten teleost hosts.

Host species	Species richness	Dominant parasite species	Dominance index
Psettodes erumei	2	*P. thomasi*	0.98
Sillago sihama	0	–	0
Rastrelliger kanagurta	0	–	0
Otolithes ruber	2	*P. lesteri*	0.83
Saurida tumbil	1	*C. gracilis*	1
Chirocentrus nudus	1	*C. gracilis*	1
Lutjanus johnii	1	*C. gracilis*	1
Lethrinus nebulosus	2	*C. gracilis*	0.97
Acanthopagrus latus	0	–	0
Tylosurus crocodilus crocodilus	1	*C. gracilis*	1

Table 4. Sorenson qualitative similarity index (C_S) and Sorenson quantitative similarity index (C_N) between helminth communities of different teleost species.

Host species	Host species	C_S	C_N	Host species	Host species	C_S	C_N
Psettodes erumei	*Sillago sihama*	0	0	*Rastrelliger kanagurta*	*Tylosurus crocodilus crocodilus*	0	0
Psettodes erumei	*Rastrelliger kanagurta*	0	0	*Otolithes ruber*	*Saurida tumbil*	0.67	0.13
Psettodes erumei	*Otolithes ruber*	0.5	0.03	*Otolithes ruber*	*Chirocentrus nudus*	0.67	0.13
Psettodes erumei	*Saurida tumbil*	0.67	0.03	*Otolithes ruber*	*Lutjanus johnii*	0.67	0.22
Psettodes erumei	*Chirocentrus nudus*	0.67	0.03	*Otolithes ruber*	*Lethrinus nebulosus*	0.5	0.08
Psettodes erumei	*Lutjanus johnii*	0.67	0.03	*Otolithes ruber*	*Acanthopagrus latus*	0	0
Psettodes erumei	*Lethrinus nebulosus*	0.5	0.02	*Otolithes ruber*	*Tylosurus crocodilus crocodilus*	0.67	0.25
Psettodes erumei	*Acanthopagrus latus*	0	0	*Saurida tumbil*	*Chirocentrus nudus*	1	0.95
Psettodes erumei	*Tylosurus crocodilus crocodilus*	0.67	0.03	*Saurida tumbil*	*Lutjanus johnii*	1	0.5
Sillago sihama	*Rastrelliger kanagurta*	0	0	*Saurida tumbil*	*Lethrinus nebulosus*	0.67	0.92
Sillago sihama	*Otolithes ruber*	0	0	*Saurida tumbil*	*Acanthopagrus latus*	0	0
Sillago sihama	*Saurida tumbil*	0	0	*Saurida tumbil*	*Tylosurus crocodilus crocodilus*	1	0.36
Sillago sihama	*Chirocentrus nudus*	0	0	*Chirocentrus nudus*	*Lutjanus johnii*	1	0.46
Sillago sihama	*Lutjanus johnii*	0	0	*Chirocentrus nudus*	*Lethrinus nebulosus*	0.67	0.68
Sillago sihama	*Lethrinus nebulosus*	0	0	*Chirocentrus nudus*	*Acanthopagrus latus*	0	0
Sillago sihama	*Acanthopagrus latus*	0	0	*Chirocentrus nudus*	*Tylosurus crocodilus crocodilus*	1	0.33
Sillago sihama	*Tylosurus crocodilus crocodilus*	0	0	*Lutjanus johnii*	*Lethrinus nebulosus*	0.67	0.27
Rastrelliger kanagurta	*Otolithes ruber*	0	0	*Lutjanus johnii*	*Acanthopagrus latus*	0	0
Rastrelliger kanagurta	*Saurida tumbil*	0	0	*Lutjanus johnii*	*Tylosurus crocodilus crocodilus*	1	0.8
Rastrelliger kanagurta	*Chirocentrus nudus*	0	0	*Lethrinus nebulosus*	*Acanthopagrus latus*	0	0
Rastrelliger kanagurta	*Lutjanus johnii*	0	0	*Lethrinus nebulosus*	*Tylosurus crocodilus crocodilus*	0.67	0.19
Rastrelliger kanagurta	*Lethrinus nebulosus*	0	0	*Acanthopagrus latus*	*Tylosurus crocodilus crocodilus*	0	0
Rastrelliger kanagurta	*Acanthopagrus latus*	0	0				

similarity indices were the highest (1), interestingly, high, low and intermediate values of Sorenson quantitative similarity were observed. Low values of Sorenson quantitative similarity were mostly calculated for inter-specific comparisons of hosts with intermediate values of Sorenson qualitative similarity (table 4).

Discussion

The present study provides the first information on a spectrum of trypanorhynch infections of ten teleost species from the Iranian waters of the north-eastern Persian Gulf. Until now the larval trypanorhynch fauna had been studied mainly from the southern part of the Persian Gulf (El-Naffar *et al.*, 1992; Saif *et al.*, 1994; Kardousha, 1999; Hassan *et al.*, 2002). Summaries of reported larval and adult trypanorhynchs from the Persian Gulf are given in tables 5–7 (see also Palm, 2004; Haseli *et al.*, 2010).

Of the recorded four trypanorhynch species, three species of the superfamily Lacistorhynchoidea Guiart, 1927, namely, *P. lesteri*, *P. thomasi* and *P. shipleyi*, demonstrated restricted host range. They were found in *O. ruber*, *P. erumei* and *L. nebulosus*, respectively, indicating higher specificity within the sampled subset of predatory fish. This is in contrast to the occurrence of the cosmopolitan *C. gracilis* (see Palm, 2004) which infected 7 of 10 fish species. This situation is similar to an earlier investigation along the north-east Brazilian coast by Palm (1997). Within that study, *C. gracilis* was the trypanorhynch cestode with the widest host range, which could be isolated from 10 fish species out of the 57 sampled fish species from 30 families. The co-infection with another pseudolacistorhynchid, *Pseudolacistorhynchus noodti*, from *Pseudupeneus maculatus* and *Scomberomorus maculatus*, and

Table 5. Reported larval trypanorhynchs belonging to families Tentaculariidae, Rhopalothylacidae and Pterobothriidae in teleost species from the Persian Gulf.

Parasite species	Fish host	Location
Family Tentaculariidae		
Tetrarhynchus sp.[7]	*Epinephelus coioides*	I
Tentacularia coryphaenae[2]	*Euthynnus affinis*	A,B,D,G
Nybelinia sp.[1]	*Saurida tumbil*	B
	Upeneus tragula	A
Nybelinia indica[2&6]	*Alepes djedaba*[2]	G
	Epinephelus tauvina[6]	H
	Nemipterus Japonicus[6]	H
	Upeneus tragula[6]	H
Heteronybelinia elongata[1&2]	*Lethrinus lentjan*[2]	G
	Lutjanus kasmira[2]	G
	Pampus argenteus[1&2]	B,G
	Saurida tumbil[2]	G
Heteronybelinia sp.[1&2]	*Trichiurus lepturus*[1&2]	D,G
Family Rhopalothylacidae		
Pintneriella musculicola[4&6]	*Epinephelus chlorostigma*[6]	H
	Epinephelus tauvina[4]	E
	Lethrinus nebulosus[6]	H
Family Pterobothriidae		
Pterobothrium sp.[1,2,5&9]	*Aesopia cornuta*[1]	D
	Caranx sp.[5]	C
	Cephalopholis miniata[2]	G
	Epinephelus areolatus[1]	B
	Epinephelus chlorostigma[1]	A
	Saurida tumbil[1]	A
	Sphyraena jello[1]	D
	Thunnus tonggol[9]	C
	Trichiurus lepturus[1]	A
Pterobothrium heteracanthum[2]	*Aesopia cornuta*	G
	Arius thalassinus	G
	Carangoides malabaricus	G
	Epinephelus areolatus	G
	Epinephelus chlorostigma	G
	Psettodes erumei	G
	Saurida tumbil	G
	Sphyraena jello	G
	Trichiurus lepturus	G

1. El-Naffar *et al.* (1992); 2. Kardousha (1999); 3. Haseli (2005); 4. Hassan *et al.* (2002); 5. Mirzayans (1970); 6. Palm (2004); 7. Peighan *et al.* (2004); 8. Saif *et al.* (1994); 9. Sazandegi (1996); 10. Tirgari *et al.* (1975). A. Abu Dhabi; B. Dubai and Sharjah; C. Iranian waters; D. Ras al Khaimah; E. The coasts of Bahrain, Oman, Qatar and the United Arab Emirates; F. The coast of Qatar; G. The coast of UAE; H. The Persian Gulf; I. Western part of the Persian Gulf, Iran.

Table 6. Reported larval trypanorhynchs belonging to families Lacistorhynchidae, Pseudotobothriidae and Otobothriidae in teleost species from the Persian Gulf. See table 5 for abbreviations.

Parasite species	Fish host	Location
Family Lacistorhynchidae		
Protogrillotia arabiensis[6]	*Siganus javus*	H
Pseudogrillotia sp.[2]	*Lethrinus erythracanthus*	G
Pseudogrillotia spratti[2]	*Liza macrolepis*	G
Pseudogilquinia thomasi[6]	*Psettodes erumei*	H
Pseudogilquinia kardoushi[6]	*Argyrops filamentosus*	H
	Lethrinus erythracanthus	H
	Psettodes erumei	H
Pseudogilquinia microbothria[6]	*Parupeneus ciliatus*	H
Grillotia sp.[10]	*Thunnus thynnus*	C
Callitetrarhynchus gracilis[2&6]	*Alepes djedaba*[2]	G
	Euthynnus affinis[2&6]	G
	Lethrinus erythracanthus[2]	G
	Nemipterus japonicus[2]	G
	Saurida tumbil[2]	G
	Scomberoides commersonnianus[2]	G
	Sphyraena barracuda[2]	G,H
	Trichiurus lepturus[2]	G
Callitetrarhynchus speciosus[2,4&6]	*Arius thalassinus*[6]	H
	Cephalopholis hemistiktos[6]	H
	Epinephelus areolatus[2]	G
	Lethrinus nebulosus[4]	E
Callitetrarhynchus sp.[2&7]	*Argyrops filamentosus*[2]	G
	Carangoides malabaricus[2]	G
	Cephalopholis miniata[2]	G
	Epinephelus chlorostigma[2]	G
	Epinephelus coioides[7]	I
	Epinephelus tauvina[2]	G
	Lethrinus nebulosus[2]	G
	Lutjanus coccineus[2]	G
	Lutjanus fulviflamma[2]	G
	Lutjanus johnii[2]	G
	Lutjanus kasmira[2]	G
	Nemipterus peronii[2]	G
	Psettodes erumei[2]	G
	Saurida undosquamis[2]	G
	Selaroides leptolepis[2]	G
	Sphyraena jello[2]	G
Family Lacistorhynchidae		
Floriceps sp.[1&6]	*Aesopia cornuta*	A
	Alepes djedaba	A
	Carangoides malabaricus	A
	Cephalopholis miniata	B
	Epinephelus areolatus	B
	Epinephelus chlorostigma	B
	Epinephelus tauvina	A
	Lethrinus erythracanthus	D
	Lethrinus lentjan	D
	Lethrinus nebulosus	A
	Liza macrolepis	A
	Lutjanus coccineus	B
	Lutjanus fulviflamma	B
	Lutjanus kasmira	D
	Nemipterus peronii	B
	Pampus argenteus	D
	Parastromateus niger	B
	Pomadasys argenteus	D
	Saurida undosquamis	D
	Sphyraena jello	B
	Upeneus tragula	A
Floriceps minacanthus[6]	*Cephalopholis hemistiktos*	H
Family Pseudotobothriidae		
Pseudotobothrium dipsacum[6&2]	*Epinephelus chlorostigma*[6]	F
	Epinephelus tauvina[6]	F
	Psettodes erumei[2]	H
Family Otobothriidae		
Symbothriorhynchus tigaminacantha[6]	*Nemipterus japonicus*	H

Table 7. Reported adult trypanorhynchs from the Persian Gulf.

Parasite species	Fish host	Parasite species	Fish host
Family Tentaculariidae		Family Eutetrarhynchidae	
Kotorella pronosoma	*Himantura* cf. *uarnak*	*Eutetrarhynchus* sp.	*Himantura imbricata*
	Rhynchobatus cf. *djiddensis*		*Rhinobatos* cf. *punctifer*
Kotorella sp.	*Himantura imbricata*	*Oncomegoides celatus*	*Himantura* sp.
Nybelinia sp. I	*Rhizoprionodon acutus*	*Parachristianella monomegacantha*	*Himantura* cf. *uarnak*
Nybelinia sp. II	*Himantura imbricata*		*Pastinachus* cf. *sephen*
Heteronybelinia heteromorphi	*Carcharhinus* cf. *dussumieri*		*Rhynchobatus* cf. *djiddensis*
Family Pterobothriidae		*Parachristianella indonesiensis*	*Himantura* cf. *uarnak*
Pterobothrium lesteri	*Gymnura* cf. *poecilura*		*Himantura* sp.
Family Lacistorhynchidae			*Pastinachus* cf. *sephen*
Pseudogrillotia perelica	*Carcharhinus* cf. *dussumieri*		*Rhynchobatus* cf. *djiddensis*
Pseudogrillotia sp.	*Carcharhinus* cf. *dussumieri*	*Parachristianella* sp.	*Himantura imbricata*
Callitetrarhynchus gracilis	*Carcharhinus* cf. *dussumieri*	*Pseudochristianella southwelli*	*Rhinobatos* cf. *punctifer*
	Carcharhinus cf. *sorrah*	*Prochristianella macracantha*	*Pastinachus* cf. *sephen*
	Rhizoprionodon acutus	*Prochristianella* spp.	*Aetomylaeus* cf. *nichofii*
Family Otobothriidae			*Himantura imbricata*
Proemotobothrium southwelli	*Carcharhinus* cf. *dussumieri*		*Himantura* sp.
	Gymnura cf. *poecilura*		*Pastinachus* cf. *sephen*
	Rhizoprionodon acutus	*Dollfusiella* spp.	*Aetomylaeus* cf. *nichofii*
Proemotobothrium sp.	*Carcharhinus* cf. *dussumieri*		*Aetomylaeus maculatus*
Otobothrium carcharidis	*Carcharhinus* cf. *dussumieri*		*Himantura* cf. *uarnak*
	Carcharhinus cf. *sorrah*		*Himantura imbricata*
	Rhizoprionodon acutus		*Himantura* sp.
Otobothrium sp.	*Carcharhinus* cf. *dussumieri*		*Pastinachus* cf. *sephen*
	Rhizoprionodon acutus		*Rhinobatos* cf. *punctifer*
Family Mixodigmatidae			
Halysiorhynchus macrocephalus	*Pastinachus* cf. *sephen*		
	Rhynchobatus cf. *djiddensis*		
Trygonicola macropora	*Himantura* sp.		
	Himantura cf. *uarnak*		
	Pastinachus cf. *sephen*		
	Rhinobatos cf. *punctifer*		
Family Eutetrarhynchidae			
Eutetrarhynchus platycephali	*Himantura* sp.		
	Pastinachus cf. *sephen*		
	Rhinobatos cf. *punctifer*		

another pterobothriid *Pterobothrium* sp. from *Citharichthys spilopterus*, showed a similar narrow host range as was observed within the present study. It seems as if the recorded combination of representatives from these three lacistorhynchoid families and the established host range are similar along the tropical north-eastern coast of Brazil and the Persian Gulf.

The record of *C. gracilis* from a range of different hosts in the Persian Gulf supports earlier investigations (e.g. Palm, 1997), and the low host specificity (Palm & Caira, 2008) and cosmopolitan distribution (Palm, 2004) of the species. Similarly, Abdou & Palm (2008) recorded *C. gracilis* in a range of different intermediate hosts in the Red Sea. Such a distribution pattern is promoted by the omnipresence of a variety of carcharhinid elasmobranchs as definitive hosts in coastal tropical regions, combined with restricted host specificity in both second intermediate and definitive hosts. Palm *et al.* (1994) and Palm (1997) proposed a four-host cycle for *C. gracilis*, including small pelagic Carangidae and Clupeidae for the first stage, and larger predatory fish, mostly Carangidae and Scombridae, for the second stage of the plerocerci. Palm & Caira (2008) showed that the average value of host specificity (H_S) for final larval stages of 63 trypanorhynch species was 6.29 (euryxenous), and the value for *C. gracilis* was 8.61 (euryxenous). The H_S recorded herewith for *C. gracilis* from teleosts in the Persian Gulf was 8.26, also euryxenous. Two new host records from *C. nudus* and *T. crocodilus crocodilus* also suggest that more studies can further extend the already known wide host range for *C. gracilis*.

The trypanorhynch cestode fauna recorded so far from the Persian Gulf demonstrates a predominance of eutetrarhynchoid and lacistorhynchoid species, with only few tentacularioids or gymnorhynchoids. This might be explained with missing faunistic components in the Gulf, such as big pelagic sharks that are common hosts for gymnorhynchoids. Another possible explanation is the lack of potential first intermediate hosts, the most important stage in the completion of the life cycle of trypanorhynchs (Palm *et al.*, 1994). Although El-Naffar *et al.* (1992) and Kardousha (1999) reported some tentaculariid species from the south of the Persian Gulf, not a single specimen belonging to the superfamily Tentacularioidea Poche, 1926 has been reported from the sampled teleosts in the northern part of the Persian Gulf.

According to Palm (2004), the life cycle includes four or even more hosts, with copepods as first, euphausiids or schooling fish as second intermediate hosts and fish as third or more intermediate or paratenic hosts. Food resources, depth, salinity and temperature might influence the distribution and species composition of required copepod first intermediate hosts (Islam *et al.*, 2005; Gaard *et al.*, 2008). Euphausiids as second intermediate hosts for tentaculariids might also be unevenly distributed. Zhaoli (2007) and Yoon *et al.* (2000) demonstrated that temperature, salinity and chlorophyll *a* concentration are important ecological factors that determine spatial distribution of euphausiids. Hunter (1983) and Reynolds (1993) stated that the salinity of the counterclockwise water current in the Persian Gulf can be influenced by rivers in the north (e.g. Tigris, Euphrates) leading to less saline waters in the Strait of Hormuz at the surface. Emery (1956) demonstrated that the bottom of the Persian Gulf is mostly muddy in the north and mostly sandy in the south, and Ebrahimi *et al.* (2008) showed that salinity increased horizontally toward the west of the Persian Gulf. These ecological differences in the north and south of the Persian Gulf might play a role in the uneven distribution of the recorded trypanorhynchs.

The highest value (1) of the Sorenson qualitative similarity and low values of Sorenson quantitative similarity indices can be explained by the low diversity and high dominance of the trypanorhynch component community in the sampled fish. The high Sorenson qualitative similarity (1) combined with the high quantitative similarity (0.95) that was observed for *S. tumbil* and *C. nudus* can be explained by a high prevalence and mean abundance of *C. gracilis* in both hosts. It is worth mentioning that there was no significant difference of the prevalence and mean abundance in these hosts, though representing different fish families. This can only be explained by a similar size and feeding ecology of these species (Fischer *et al.*, 1990; Sommer *et al.*, 1996), demonstrating that the feeding ecology of the fish must have a major important role for infection with *C. gracilis* in the Persian Gulf.

Regarding the high diversity of trypanorhynchs in the Persian Gulf (Haseli *et al.*, 2010), this semi-enclosed marine ecosystem has the capacity for the completion of a variety of life cycles. According to Palm (2004) and Southwell (1929, 1930), it seems that the east of the Indian Ocean, the Indonesian archipelago and Sri Lanka share the same species, resulting from connected water bodies. The Persian Gulf can be invaded by trypanorhynchs due to their low host specificity (Palm & Caira, 2008) and wide zoogeographical distribution of many of their host fish species (Fischer & Whitehead, 1974; Compagno, 1984; Fischer & Bianchi, 1984; Carpenter *et al.*, 1997).

Among the ten studied commercially important teleosts in the Iranian waters of the Persian Gulf, musculature infection was restricted to *P. erumei* at a prevalence of 62.9% and a range of intensity of 1–22. This relatively high infection of muscles with the large plerocerci of *P. thomasi* may cause concern for marketing and public health (see Pelayo *et al.*, 2009). It is recommended that *P. erumei* be well cooked and freed from the most obvious trypanorhynch larvae before the fish is sold and considered for human consumption.

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