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Taxonomic characterization of five species of emperor fishes (Actinopterygii: Eupercaria: Lethrinidae) based on external morphology, morphometry, and geographic distribution in the northwestern Indian Ocean

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Abstract

Species of the genus *Lethrinus*, commonly referred to as emperor fishes, mainly distributed in the Indo–West Pacific, including the Persian Gulf and Gulf of Oman are poorly known. It is difficult to characterize them morphologically, as there are no distinguishing meristic features for the majority of species. We studied the morphological features of 65 specimens representing the genus *Lethrinus* to define and identify the species involved. Among the morphological characters commonly considered in this type of study, we also included new, previously undescribed characters. The results of Tukey's post hoc HSD test for metric and meristic variables, which showed significant differences between species in ANOVA, indicate that most metric traits and the number of scale rows above the lateral line differ significantly among the five morphotypes distinguished. Principal component analysis (PCA) and discriminant function analysis (DFA) effectively showed the morphometric variation between these morphotypes. The characteristics of body depth, head length, pectoral fin length, and caudal fin length are the most distinguishing diagnostic at the species level. We determined that the collected fish specimens represented: *Lethrinus borbonicus* Valenciennes, 1830, *Lethrinus crocineus* Smith, 1959, *Lethrinus lentjan* (Lacepède, 1802), *Lethrinus microdon* Valenciennes, 1830, and *Lethrinus nebulosus* (Forsskål, 1775). We also confirmed their validity as distinct species. Notably, *L. crocineus*, previously known only from the western Indian Ocean (Africa and Socotra), is now reported for the first time from the Persian Gulf and the Gulf of Oman. Lastly, a distribution map for the *Lethrinus* species is included.

Keywords

Gulf of Oman, *Lethrinus*, morphological features, new record, Persian Gulf, taxonomy

Introduction

The Persian Gulf and Gulf of Oman in the northwestern Indian Ocean (NIO) are recognized as two of the largest brackish-water environments of outstanding universal value in the world (Maghsoudlou et al. 2019). The uniqueness of these ecoregions is outstanding due to the description of endemic species and clades with high genetic diversity in recent years (Asgharian et al. 2011; DiBattista et al. 2017; Torquato et al. 2019; Rabaoui et

al. 2019; Damadi et al. 2020; Alavi-Yeganeh et al. 2021; Mehraban et al. 2021; Sadeghi et al. 2021; Esmaeili et al. 2022; Damadi et al. 2024). These ecoregions are dynamic coastal environments characterized by a complex system of oceanic processes, and ecological and physiological features (Coles 2003; Feary et al. 2010; Burt et al. 2011; Maghsoudlou et al. 2019). Given the physical complexity, high biodiversity, and endemism of the NIO, it has been considered a model system for the study of processes and patterns that influence the connectivity and fragmentation of marine populations (DiBattista et al. 2017; Torquato et al. 2019; Mehraban et al. 2021). The Lethrinidae Bonaparte, 1831 are a group of large coral reef fishes found mainly in the Indo–West Pacific (IWP) (Carpenter and Allen 1989; Fricke et al. 2024). Members of this family are commonly known as the emperor breams and the family comprises two subfamilies, five genera, and 45 valid species (Fricke et al. 2024). The subfamily Lethrininae comprises only a single genus, *Lethrinus* Cuvier, 1829, and is considered a taxonomically difficult group (Smith 1959; Sato 1971 [cited after Healey et al. 2018]; Carpenter and Allen 1989). As the *Lethrinus* are generally large fish that are exploited by commercial fisheries and sold in fish markets throughout the Indo–Pacific (Carpenter and Allen 1989; Ebisawa and Ozawa 2009), sound fisheries management at the local or regional level is also an issue. In all these cases, the importance of a reliable and effective tool for unambiguous species identification becomes clear, as a lack of, or incorrect, knowledge of taxonomy distorts the conclusions drawn from the comparative results. The emperor fishes of the genus *Lethrinus* differ from fishes of other lethrinid genera by the number of scale rows above the lateral line to the middle spines of the dorsal fin, the scaleless cheek, the smooth edge of the preopercle, and the longer snout (Carpenter 1997). The meristic values of many species overlap considerably and aspects of body shape, proportional measurements, and coloration such as spots, bars, bands, and stripes, are valuable in distinguishing many species (Smith 1959; Sato 1971 [cited after Healey et al. 2018]; Randall 1995; Carpenter 1997; Borsa et al. 2010). The *Lethrinus* species were revised recently, and two new species have been described based on morphological and molecular diagnoses (Carpenter and Randall 2003; Allen et al. 2021), and eight other, potentially new, recently collected species await description (Lo Galbo et al. 2002; Borsa et al. 2013; Mekkawy 2017; Healey et al. 2018). Despite these recent phylogenetic assessments and the taxonomic changes proposed therein, there is still a large gap in basic subtle morphological differences among *Lethrinus* species. Anatomical characteristics of larvae and adults, geographical distribution, and external morphological data are incomplete and scattered in the literature (Smith 1959; Sato 1971 [cited after Healey et al. 2018]; Carpenter and Allen 1989). Members of this genus are particularly difficult to identify in the late larval, juvenile, and adult stages because their body shapes are often similar, and their color patterns vary according to age, behavior, condition, or environment (Wilson 1998; Ponton et al. 2013). Of the 30 species of the genus, four occur in the Persian Gulf and the Gulf of Oman, including *Lethrinus borbonicus* Valenciennes, 1830, *Lethrinus lentjan* (Lacepède, 1802), *Lethrinus microdon* Valenciennes, 1830, and *Lethrinus nebulosus* (Forsskål, 1775) (see Fricke et al. 2024). The first data on *Lethrinus* species in the Persian Gulf and the Gulf of Oman come from Blegvad and Løppenthin (1944), who described *L. nebulosus* and *Lethrinus miniatus* (Forster, 1801). Then, Carpenter et al. (1997) and Grandcourt (2012) added three species, *L. borbonicus*, *L. lentjan*, and *L. microdon* from the southern part of the Persian Gulf. Subsequently, *L. miniatus* was removed from the checklist of fishes in these ecoregions (Carpenter et al. 1997; Grandcourt 2012; Psomadakis et al. 2015). In some cases, molecular phylogenetic studies on the genus *Lethrinus* have suggested that both *L. lentjan* and *L. nebulosus* probably form a hidden diversity in the Persian Gulf and Gulf of Oman (Asgharian et al. 2011; Mekkawy 2017). In addition, some *Lethrinus* species were listed in the general ecological and biology works in the ecoregions (Grandcourt et al. 2006; McIlwain et al. 2006; Taghavi Motlagh et al. 2010). Our specific objectives were to:

- Evaluate the external morphological characters used to diagnose the species for the Persian Gulf and Gulf of Oman representatives.
- Examine the morphometric and meristic variation among *Lethrinus* species based on univariate and multivariate analysis.
- Investigate the distribution and diversity of *Lethrinus* species of the Persian Gulf and Gulf of Oman.
- Report a new record of *L. crocineus* for the first time from these ecoregions.

Material and methods

Specimen collection. A total of 65 specimens were collected between 5 and 50 m depth along the Persian Gulf and the Gulf of Oman at eight stations (Fig. 1). The specimens were collected using gillnets with mesh sizes ranging from 11 to 16 cm, as well as hook-and-line, during the months of May and July in 2022 and 2023. All specimens were photographed on the left side with a Canon Powershot A3300 16-megapixel digital camera positioned on a tripod on a table with a millimeter scale. The collected specimens were preserved in 10% formalin solution and stored in the Zoological Museum of the Ferdowsi University of Mashhad (ZMFUM), Iran (Suppl. material 1). All specimens were identified using the taxonomic keys relevant to the regions (Blegvad and Løppenthin 1944; Randall 1995; Carpenter et al. 1997).

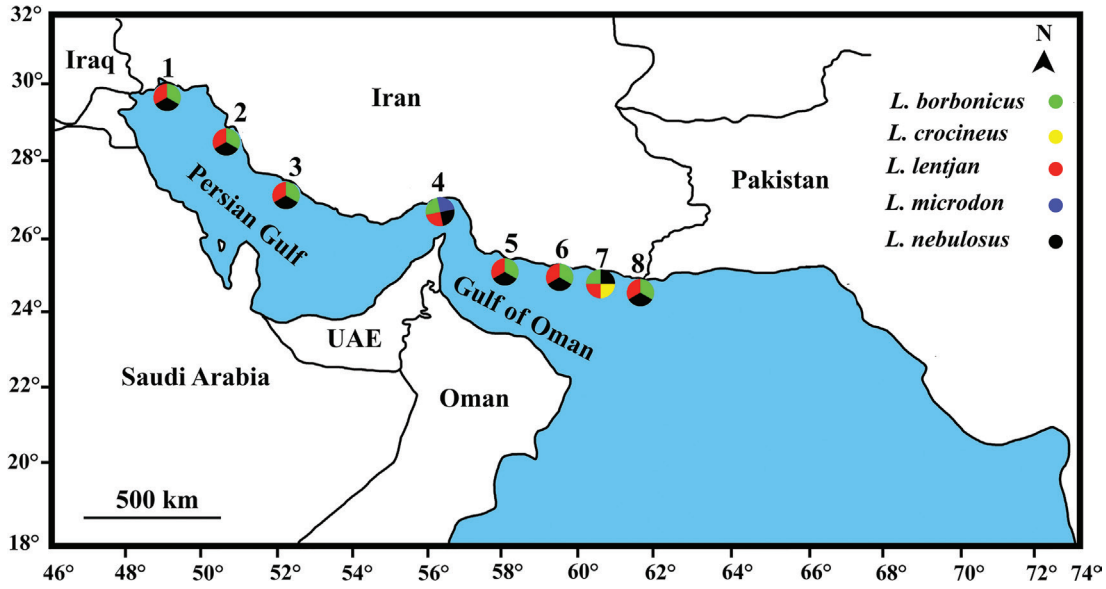

Figure 1. Geographic distribution of *Lethrinus* species in the Persian Gulf and the Gulf of Oman. Abbreviations: 1 = Hendijan, 2 = Bushehr, 3 = Kangan, 4 = Qeshm (Naz Island), 5 = Jask, 6 = Pozm, 7 = Tis, 8 = Beris.

Morphometric analysis. A total of 16 morphometric traits were measured in the laboratory for each specimen. Nine meristic features were counted. Counts and measurements were taken as far as possible on the left side of the fish, following standard methods for *Lethrinus* taxonomy (Allen et al. 2021). The morphometric methods, meristic methods, and the color patterns correspond to those of Allen et al. (2021). For brevity, these characters will be abbreviated as follows: **counts:** DFS = dorsal-fin spines; DFR = dorsal-fin rays; AFS = anal-fin spines; AFR = anal-fin rays; PFR = pectoral-fin rays; LLS = lateral-line scales; SALL = scale rows above lateral line; SBLL = scale rows below lateral line; LSACP = scale around caudal-peduncle; SPS = supratemporal patch of scales. **Measurements:** BD = body depth; HL = head length; OD = orbit diameter; POL = preorbital length; UJL = upper-jaw length; CPD = caudal-peduncle depth; CPL = caudal-peduncle length; PDL = predorsal length; PAL = preanal length; PPL = prepelvic length; LDFB = length dorsal-fin base; LAFB = length anal-fin base; LPF = length pectoral fin; LCF = length caudal fin; OD = orbit diameter [% of HL]. All morphometric variables were divided by the standard length (SL) and head length (HL) before analyses to eliminate the size effect. The data were tested for normality using the Shapiro–Wilk test and for homogeneity using the Levene test. Sex determination was based on the gonads according to Marriott et al. (2010). MANOVA test was used to assess sexual dimorphism between males and females. All statistical analyses were performed in PAST v. 4.03 (Hammer 2020) and SPSS v. 23 (SPSS Inc., Chicago IL). For morphometric traits, one-way analysis of variance (ANOVA) and Tukey's post-hoc test were performed to assess significant differences between species. Subsequently, significant variables were then subjected to PCA and DFA. Given that the use of ratios can result in misleading correlations (Atchley et al. 1976), we utilized the method suggested by Sagnes et al. (1997). Ponton et al. (2013) also outlined a data treatment approach, in line with Sagnes et al. (1997), that was employed to prevent any biases arising from the use of ratios and proportions in measuring fish body characteristics. Prior to being subjected to double-centered PCA, all linear measurements, except SL, were log10 transformed. PCA is an effective method for reducing morphometric data and extracting independent variables. DFA is a predictive model for group membership. The source of discrimination between samples was based on the percentage of correctly and incorrectly classified fish. The holdout leave-one-out cross-validation procedures proposed by Lachenbruch (1967) were also performed to calculate the misclassification rate of DFA.

Ethical statement. Handling and sampling in the Persian Gulf and the Gulf of Oman were approved by the Ethic-Scientific Committee of the Ferdowsi University of Mashhad, Iran, and the Iranian Fisheries Organization (scientific permit IR.UM.REC.1400.183).

Results

Examining *Lethrinus* specimens collected in the Persian Gulf and the Gulf of Oman revealed a total of five *Lethrinus* species. These species are *L. borbonicus*, *L. crocineus*, *L. lentjan*, *L. microdon*, and *L. nebulosus*. The presently reported findings of *Lethrinus crocineus* represent a new record for the marine fauna of the Persian Gulf and the Gulf of Oman. Below are brief descriptions of the morphometric and meristic characteristics of these species as well as univariate and multivariate analyses.

Family Lethrinidae
Genus *Lethrinus* Cuvier, 1829

Lethrinus borbonicus Valenciennes, 1830

English common name: snubnose emperor

Lethrinus borbonicus Valenciennes in Cuvier and Valenciennes, 1830.—Cuvier and Valenciennes (1830): 125; syntypes: MNHN 0000-9092 (1), 0000-9373 (2); Type locality: southwestern Indian Ocean (western Mascarenes: Réunion: Saint Denis).

Material examined. ZMFUM-LE-26-34, 9 specimens (Suppl. material 1), May 2022 to April 2023, depth 20–30 m.

Description. Dorsal-fin rays X, 9; anal-fin rays III, 8; pectoral-fin rays13; tubed lateral-line scales 46–47; 5.5 transverse scale rows above lateral line; 15–16 transverse scale rows below lateral line; 13–15 lower series of scale around caudal-peduncle; high-bodied forms; numerous small scales on inside of pectoral fin base; molariform teeth; cheek without scales; body gray; fins mostly light brown; upper half of body darker than rest of body; posterior margin of opercular membrane gray.

Lethrinus crocineus Smith, 1959

English common name: yellowtail emperor

Fig. 2A

Lethrinus crocineus Smith, 1959. Holotype: SAIAB 22; Paratypes: not studied; Type locality: western Indian Ocean (Mozambique: Pinda).

Material examined. ZMFUM-LE-11-22, 12 specimens (Suppl. material 1), May 2022 to July 2023, depth 40 m.

Description. Dorsal-fin rays X, 9; anal-fin rays III, 8; pectoral-fin rays13; tubed lateral-line scales 46–47; 5.5 transverse scale rows above lateral line; 15–17 transverse scale rows below lateral line; 15–16 lower series of scale around caudal-peduncle; high-bodied forms; numerous small scales on inside of the pectoral fin base; molariform teeth; cheek white and without scales; body gray; fins usually yellowish, except pelvic fin.

Lethrinus nebulosus (Forsskål, 1775)

English common name: spangled emperor

Fig. 2B

Sciaena nebulosa Forsskål in Niebuhr, 1775.—Niebuhr (1775): 52; Holotype: ZMUC P49345; No locality stated (Red Sea).

Material examined. ZMFUM-LE-44-68, 25 specimens (Suppl. material 1), May 2022 to March 2023, depth 5–30 m.

Description. Dorsal-fin rays X, 9; anal-fin rays III, 8; pectoral-fin rays13; tubed lateral-line scales 46–47; 5.5 transverse scale rows above lateral line; 15–17 transverse scale rows below lateral line; 14–15 lower series of scale around caudal-peduncle; high-bodied forms; forked caudal fin; numerous small scales on inner surface of pectoral-fin base; molariform teeth; cheek without scales; body light gray; head with light blue stripes; pale blue stripe dorsally on basal half of pectoral fin; white spots on body.

Lethrinus lentjan (Lacepède, 1802)

English common name: pink ear emperor

Fig. 2C

Bodianus lentjan Lacepède, 1802.—Lacepède (1802): 281, 293; Holotype (unique): MNHN A-7847; No locality stated (probably eastern Indian Ocean, Indonesia Java).

Material examined. ZMFUM-LE-1-10, 10 specimens (Suppl. material 1), August 2022 to July 2023, depth 5–30 m.

Description. Dorsal-fin rays X, 9; anal-fin rays III, 8; pectoral-fin rays13; tubed lateral-line scales 46–47; 5.5 transverse scale rows above lateral line; 15–16 transverse scale rows below lateral line; 14–15 lower series of scale around caudal-peduncle; high-bodied forms; some scales on inside of pectoral fin base; molariform teeth; cheek white and without scales; body gray; pectoral and caudal fins red; inner part of pectoral fin red; posterior edge of opercular membrane red.

Lethrinus microdon Valenciennes, 1830

English common name: smalltooth emperor

Fig. 2D

Lethrinus microdon Valenciennes in Cuvier and Valenciennes, 1830.—Cuvier and Valenciennes (1830): 295, Holotype: MNHN 0000-9073; Type locality: Indonesia: Molucca Islands, northeastern Pulau Buru.

Material examined. ZMFUM-LE-35-43, 9 specimens (Suppl. material 1), May 2022 to March 2023, depth 25–50 m.

Description. Dorsal-fin rays X, 9; anal-fin rays III, 8; pectoral-fin rays13; tubed lateral-line scales 47–48; 4.5 transverse scale rows above lateral line; 16–17 transverse scale rows below lateral line; 15–16 lower series of scale around caudal-peduncle; low-bodied forms; forked caudal fin; no scales on inside of the pectoral fin base; conical teeth; cheek without scales; body gray; fins brown.

Morphometrics. To characterize the morphological variation between *Lethrinus* species, morphometric features were analyzed. The MANOVA results showed no significant difference between males and females, the sexes were pooled in all analyses ($0.0511 < P < 1.0000$) (Suppl. material 2). In the one-way ANOVA analysis, 17 out of 22 traits were found to be significant ($P < 0.0000$) (Suppl. material 2). These traits included 15 morphometric and two meristic traits (Suppl. material 2). The Tukey post hoc test results showed a significant difference between all five species ($P < 0.05$). Specifically, the Tukey post hoc tests for metric traits showed the most significant differences between *L. crocineus* and *L. microdon*, while the differences in meristic variables were most significant between

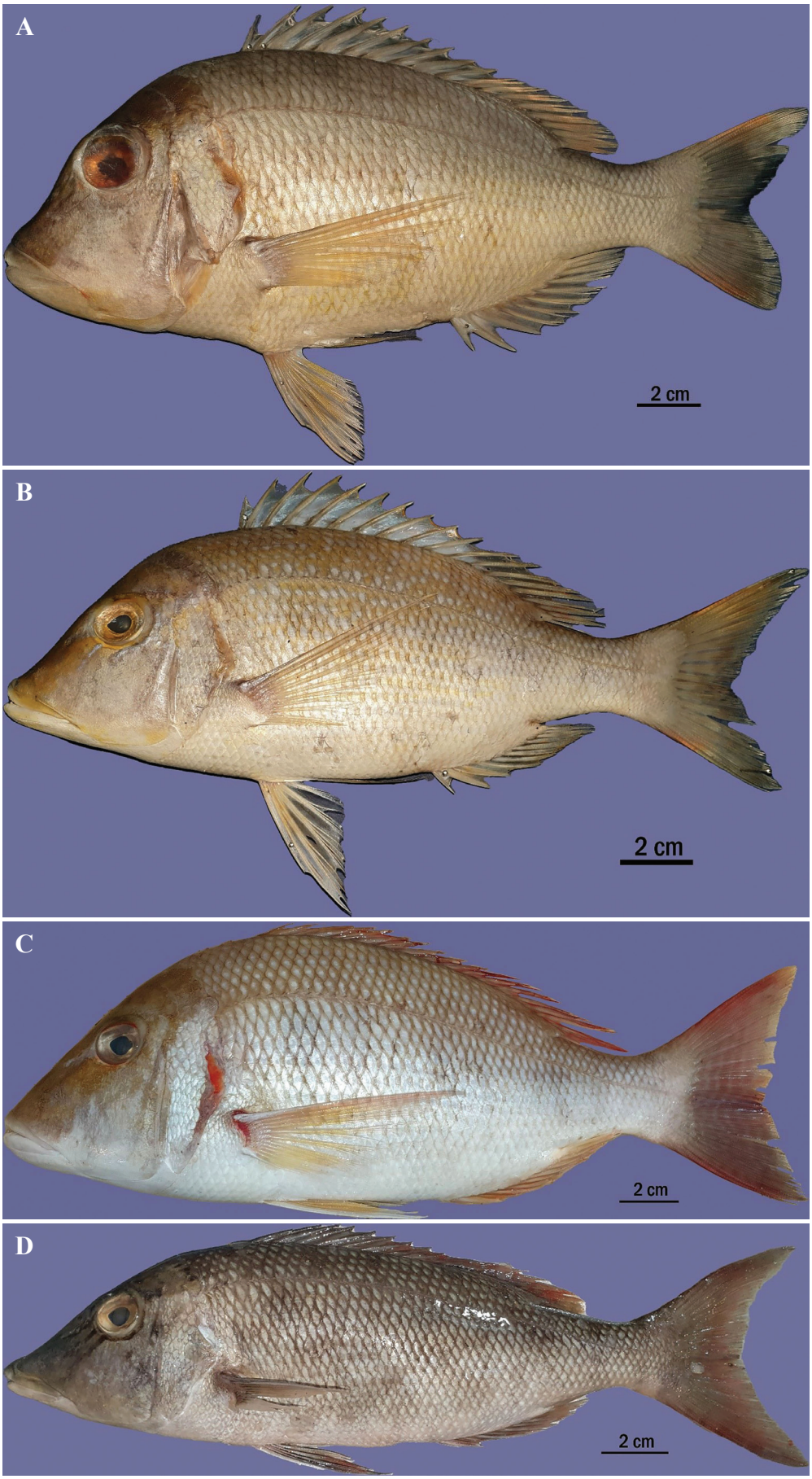

Figure 2. *Lethrinus crocineus* (**A**), ZMFUM-LE-12, (Photo by E. Damadi); *Lethrinus nebulosus* (**B**), ZMFUM-LE-48, (Photo by E. Damadi); *Lethrinus lentjan* (**C**), ZMFUM-LE-8, (Photo by E. Damadi); *Lethrinus microdon* (**D**), ZMFUM-LE-35, (Photo by E. Damadi).

L. microdon and the other species (data not shown). The boxplot of total length shows that *L. nebulosus* is generally larger than the other species; *L. microdon* is medium-sized and the other species are smaller (Fig. 3). As expected, the first principal component (PC1) on metric characters accounted for the highest proportion of variance (99.2%) (Fig. 4A). On the PC1 axis, *L. nebulosus* and *L. microdon* showed a high differentiation from *L. borbonicus*, *L. crocineus*, and *L. lentjan* in the majority of of the measured morphometric traits, including body depth, caudal peduncle depth, pectoral fin length, preorbital length, and caudal fin length. On the PC2 axis, *L. crocineus* showed significant differences from *L. microdon*. PCA on the morphometric traits showed a notable overlapping between *L. borbonicus* and *L. lentjan* on PC1 and PC2. For the majority of meristic traits, *L. microdon* showed a high differentiation from the other species due to its significant scale rows above the lateral line and supratemporal scale patch (Fig. 4B). The PCA results (Fig. 4) were well supported by the DFA analyses (data not shown). The DFA correctly classified 100% of the specimens, which was confirmed by cross-validation of specimens to species based on morphometric and meristic features.

Discussion

This study is the first univariate and multivariate analysis to determine the morphometric and meristic variation and taxonomic validation of *Lethrinus* fishes in the Persian Gulf and Gulf of Oman. The morphological examination of *Lethrinus* specimens collected from the coastal waters of the Persian Gulf and Gulf of Oman confirms the presence of the previously unreported *L. crocineus* in these ecoregions. The discovery of this species in the Persian Gulf and the Gulf of Oman indicates that there is a suitable habitat for *L. crocineus* in these ecoregions and further species of the genus *Lethrinus* could be discovered in the future. This species was previously known from the tropical regions of Africa and Socotra (Heemstra et al. 2004; Fricke et al. 2018; Zajonz et al. 2019). The occurrence of tropical fish in subtropical regions is considered one of the first indicators of climate-induced change in biodiversity (Perry et al. 2005; Munday et al. 2008; Booth et al. 2017; Wabnitz et al. 2018; Bañón et al. 2020). It is assumed that climate change has a major impact on marine biodiversity in the Persian Gulf and the Gulf of Oman (Wabnitz et al. 2018; Khajavi and Alavi-Yeganeh 2020; Damadi et al. 2021; Esmaeili and Eslami Barzoki 2023). In addition, a long-term increase in the temperature of the Persian Gulf and the Gulf of Oman is well documented (Jawad et al. 2011, Piontkovski and Chiffings 2014). Warmer water masses could cause an expansion of the distribution range of *L. crocineus* from its original one in East Africa and Socotra northwards along the northern Gulf of Oman. The presently reported findings add five species of *Lethrinus* to the list of marine fish species in these ecoregions. The low species diversity of *Lethrinus* species in the Persian Gulf and the Gulf of Oman, as compared to neighboring euryhaline environments such as the Arabian Sea (Manilo and Bogorodsky 2003, 12 spp.), the Red Sea (Golani and Fricke 2018, 10 spp.) and Socotra (Zajonz et al. 2019, 10 spp.), is somewhat surprising. This discrepancy could potentially be attributed to various factors, including oceanographic barriers, geological events, and differences in habitat structure (Feary et al. 2010; Burt et al. 2011; Ludt and Rocha 2015; Maghsoudlou et al. 2019; Torquato et al. 2019; Zajonz et al. 2022). One possible hypothesis for the observed low species diversity in the Persian Gulf and Gulf of Oman is that upwelling events along the Omani have restricted stepping-stone connections between these ecoregions and other neighboring euryhaline environments in the Indian Ocean (Glynn 1993; Burt et al. 2011). The lack of suitable habitats due to the last glacial events and environmental factors (i.e., high temperature and salinity) created barriers and altered environmental conditions that likely led to the low biodiversity in the Persian Gulf and Gulf of Oman (Sarnthein 1972; Lokier et al. 2015; Vaughan et al. 2019). Previous authors confirmed the taxonomic validity of *L. lentjan* and *L. nebulosus* (see Asgharian et al. 2011) from the Persian Gulf and Gulf of Oman and

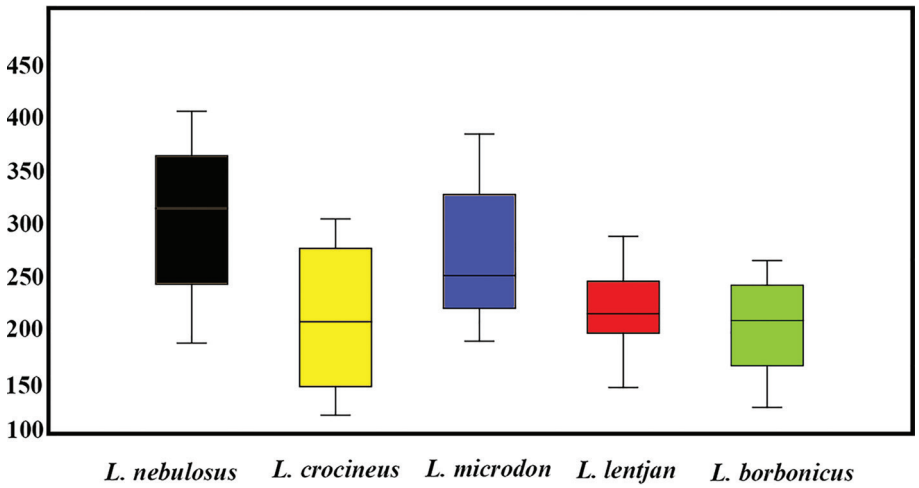

Figure 3. Total length data of the five of *Lethrinus* species samples in the presently reported study in the Persian Gulf and the Gulf of Oman.

showed some cryptic species within these species based on molecular data (Mekkawy 2017). The majority of diagnostic morphological characters at the species level were consistent with previous descriptions by Randall (1995) and Carpenter et al. (1997), except metric characters such as pectoral fin length and caudal fin length and orbit diameter. The univariate and multivariate analyses yielded the same results (Suppl. material 2; Fig. 4). Meristic and metric features showed the greatest differences between *L. microdon* and other species (Fig. 4). *Lethrinus microdon* differs from the other species studied by fewer scale rows above the lateral line (4.5 scales vs. 5.5 scales in congeners); no scales on the inside of the pectoral fin base, a deeper body, 3.2%–3.5% of SL (vs. 2.3%–2.8% in congeners); a longer pectoral fin, 3.8%–4.7% of SL (vs. 3.1%–3.7% in congeners); a deeper caudal-peduncle depth, 10.3%–11.6% of SL (vs. 8.5%–9.6% in congeners). *Lethrinus borbonicus* differs most clearly from *L. lentjan* in the posterior margin of the operculum (gray vs. red in *L. lentjan*) and the base of the pectoral fin (grey vs. red in *L. lentjan*) and a larger orbit diameter, 8.5%–14.1% of HL (vs. 4.2%–5.1% in *L. lentjan*). It differs from *L. nebulosus* in the absence of light blue stripes in front of the eyes (vs. the presence of light blue stripes in front of the eyes in *L. nebulosus*), and the often slightly convex profile of the head near the eyes (vs. profile of the head straight near the eyes in *L. nebulosus*), and a larger orbit diameter, 8.5%–14.1% of HL (vs. 4.4%–5.3% of SL in *L. nebulosus*). *Lethrinus borbonicus* is also different from *L. crocineus* by having median fins gray (vs. yellow in *L. crocineus*), a deeper body, 2.5%–2.8% of SL (vs. 2.3%–2.5% in *L. crocineus*), and a longer pectoral fin, 3.3%–3.5% in SL (vs. 3.1%–3.2% in *L. crocineus*). Based on the meristic features, *L. crocineus* could also be easily confused with *L. nebulosus* and *L. lentjan*, but it differs in having an area on the snout directly in front of the eye with a prominent hump (lacking this prominent hump in *L. lentjan*), a moderately narrow body, 2.4%–2.5% of SL (vs. 2.5%–2.8% in *L. lentjan*), the posterior margin of the operculum gray (vs. red in *L. lentjan*), the base of the pectoral fin grey (vs. red in *L. lentjan*), and the head without light blue stripes and without white spots on the body (vs.

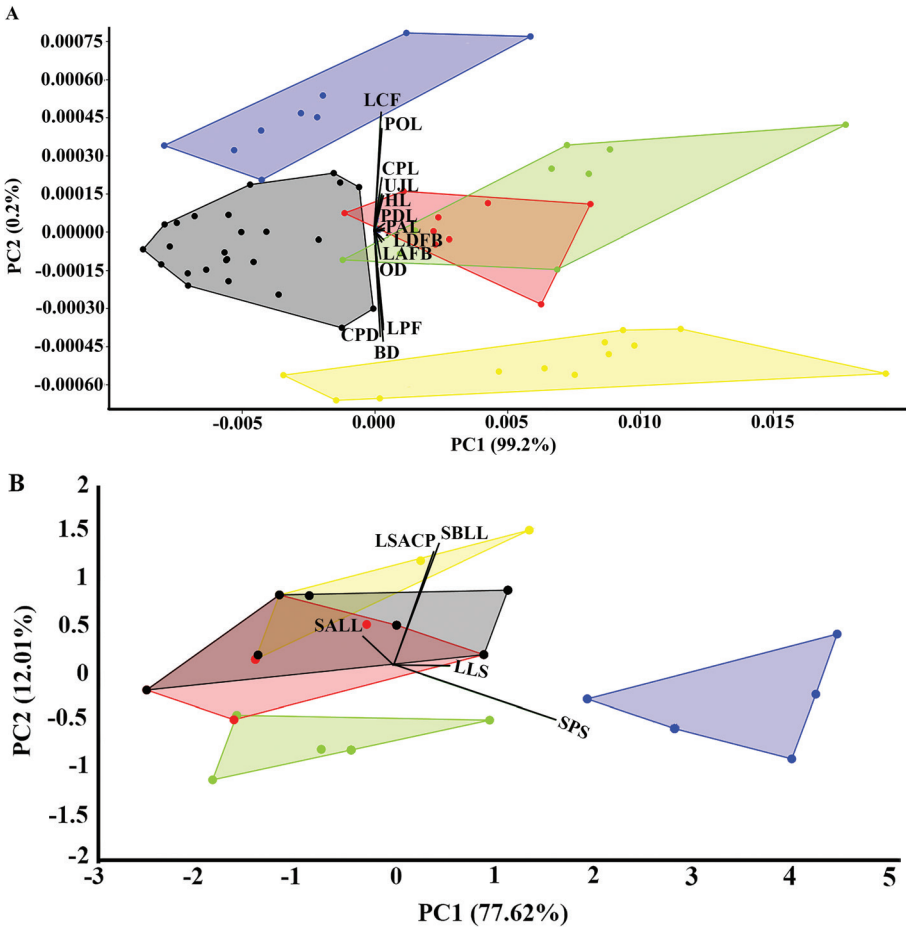

Figure 4. Principal component analysis (PCA) results of the five of *Lethrinus* species samples in the presently reported study in the Persian Gulf and the Gulf of Oman; (**A**) morphospace plotted on 14 morphometric traits; and (**B**) morphospace plotted on 10 meristic traits morphometric traits; *L. borbonicus* (green), *L. crocineus* (yellow), *L. lentjan* (red), *L. microdon* (blue), *L. nebulosus* (black). LLS = lateral-line scales; SALL = scale rows above lateral line; SBLL = scale rows below lateral line; LSACP = scale around caudal-peduncle; SPS = supratemporal patch of scales; BD = body depth; HL = head length; POL = preorbital length; UJL = upper-jaw length; CPD = caudal-peduncle depth; CPL = caudal-peduncle length; PDL = predorsal length; PAL = preanal length; PPL = prepelvic length; LDFB = length dorsal-fin base; LAFB = length anal-fin base; LPF = length pectoral fin; LCF = length caudal fin; OD = orbit diameter [% of HL].

light blue stripes on the head and white spots on the body in *L. nebulosus*). *Lethrinus nebulosus* differs from the closely related *L. lentjan* in morphometric measurements and color patterns. It has the posterior margin of the opercular membrane grey (vs. red in *L. lentjan*), the base of the pectoral fin grey (vs. red in *L. lentjan*), the head with light blue stripes and white spots on the body (vs. lack of light blue stripes on the head and lack of white spots on the body in *L. lentjan*), and a smaller head, 3%–3.2% of SL (vs. 2.6%–2.8% in *L. lentjan*). The morphometric variation of *L. microdon* appears to be associated with trophic ecology (Ali et al. 2016; Thangaraj et al. 2022). Food content analyses revealed that the main dietary components of *L. lentjan* and *L. nebulosus* were slow-moving benthic invertebrates such as mollusks, echinoderms, and crustaceans. In contrast, *L. microdon* predominantly consumed fast-moving prey such as nekton and other groups of invertebrates (Thangaraj et al. 2022). The slender body shape, jaw structure, and feeding behavior of *L. microdon* allow it to consume a far greater proportion of nekton. Given the economic value of emperor fishes in these regions, it is important to note that, besides *L. nebulosus*, the catch of other species has significantly decreased in recent years. This highlights the need to increase attention and conservation efforts to protect these species. In the future, conducting studies with larger sample sizes, if possible, and using additional geometric morphometric and genetic analyses may help clarify specific aspects related to distinguishing the species within this group.

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Supplementary material 1

List of specimens

Authors: Ehsan Damadi, Faezeh Yazdani Moghaddam, Mehdi Ghanbarifardi

Data type: xlsx

Explanation note: Specimens, localities, accession numbers and coordinates of the five *Lethrinus* species used for the morphometric analysis in the Persian Gulf and Gulf of Oman.

Link: https://doi.org/10.3897/aiep.54.118586.suppl1

Supplementary material 2

Morphological characteristics of *Lethrinus* species

Authors: Ehsan Damadi, Faezeh Yazdani Moghaddam, Mehdi Ghanbarifardi

Data type: xlsx

Explanation note: Statistically significant for each metric and meristic characteristic among the species of *Lethrinus*. Measured characteristics expressed as a percentage of standard length (%SL) and head length (%HL). Asterisks indicate significant P values: *** (< 0.001).

Link: https://doi.org/10.3897/aiep.54.118586.suppl2