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UNDERSTANDING THE EQUALITY OF TWO SPECIES OF GOATFISH

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ABSTRACT:

The goatfish genus Upeneus (Mullidae) must be investigated more extensively since there is a potential that previously unknown species might exist in less well explored places. Specifically, this study is focused on the SWIO as well as the so-called japonicus-group of Upeneus, which is a taxonomic species group in its own right. During a recent visit to Sodwana Bay in KwaZulu–Natal, South Africa, researchers discovered and collected the newly described Floras goatfish, U. floras, which they named after the Floras River in Italy. All 13 japonicus-group taxa were compared based on their colour patterns and morphological traits, as well as their COI barcoding results. In the coastal region between Angoche, N Mozambique, and KwaZulu-Natal, the new species partially overlaps with two other similar species, U. guttate, which is widely distributed in the Indo-West Pacific, and U. saiab, which is considered to be endemic to a small area off the coast of Angoche, South Africa. Further comparisons were made between U. Seychellois's from the Seychelles Bank and U. Pori from the Mediterranean (in the form of a Lessepsian migrant), the Northern Red Sea, and Madagascar as additional japonicus-group species in the SWIO. New taxonomic descriptions and diagnoses of the two previously misdiagnosed species, U. floras and U. guttatus, are provided, taking into account the size and population differences of the species, respectively. It has been reported that three specimens of U. pori from NE Madagascar have been discovered, as well as a newly discovered colour photograph of a previously known species from SW Madagascar. Upeneus floras is distinguished from Upeneus guttatus and Upeneus pori by the length of its head, the height of its first dorsal fin, and the number of gills rakers on its gills. There are many distinguishing characteristics between Upeneus guttatus and the other two species, including disproportionally bigger anterior dorsal-fin spines, yellow or creamy-white barbless, and fewer pectoral fin rays. When COI barcoding was utilised, however, it was discovered that there was no significant divergence between U. guttatus, U. floras, and U. pori.

1. INTRODUCTION:

There are 42 recognised species of goatfish in the Upeneus (Mullidae) genus, 13 of which have been placed in the so-called japonicus-group. The number of dorsal-fin spines is the most distinctive feature of this taxonomic group. There are seven dorsal-fin spines in japonicus-group species, while there are eight spines in 28 of the 29 other Upeneus species, including the newly identified U. heterospinus Uiblein & Pavlov, 2019. Several morphometric, meristic, and colour features, as well as geographic distribution, allow this species to be separated from the japonicus-group species. Many new species have been added to the japonicus-group lately. N Australia and Vanuatu have added seven new species to our knowledge since 2011. It has been suggested that there may be additional japonicus-group species still to be discovered, based on recent descriptions of the species. That's why we need to keep exploring these locations and collect additional specimens using different ways and from fish markets, record the colour of living or freshly-deceased fish, and check over all the existing museum material for any problems.

There are just a few of records for Upeneus saiab and U. seychellensis, both of which are found on the Seychelles Bank in the northeastern part of Mozambique. To far, it has been found in waters as far apart as the Red Sea and the Mediterranean (as Lessepsian migrant). A single specimen was found in Madagascar by Uiblein and Heemstra (2010). Over half a billion miles of ocean separate this and any other japonicus-group species, including Upeneus guttatus, making it the most widely distributed. The junior synonym of U. guttatus, U. crosnieri Fourmanoir & Guézé, 1967, was verified for the SWIO as U. guttatus in Madagascar. Uiblein & Heemstra (2010) confirmed the distribution information supplied by Randall & Kulbicki by reporting data from Kenya, Mozambique, the Mascarene Islands, and the Seychelles (2006). A single well-preserved specimen was all that was needed to establish the existence of U. guttatus off the coast of KwaZulu-Natal, South Africa by Uiblein & Heemstra (2010).

Some new species of japonicus have lately been discovered in the SWIO, mainly off the coast of KwaZulu-Natal. On the N KwaZulu-Natal coast, in Sodwana Bay, two in-situ pictures of shoaling goatfish over sandy bottom near Ribbon Reef were released by Uiblein & Lisher (2013). The authors hypothesised that this species was also found along the KwaZulu-Natal coast since the overall colour pattern matched that of U. pori and because of recent reports of this species from the SWIO (Madagascar). It was not possible to collect any specimens from the Sodwana Bay population. Uiblein & Gledhill (2015), two years later, when comparing populations of U. guttatus over its whole range, found that the population from KwaZulu-Natal had much longer heads and lower first dorsal fins. Two of these specimens were later documented in colour images that were taken immediately after they were captured. There are a number of ways to study the coloration of goatfish, including seeing them in the wild and preserving them for further study.

In Sodwana Bay, three specimens were spear-gunned in April 2017. Specimens were photographed and tissue samples were obtained after the capture was made, and the specimens were conserved and added to the SAIAB collection. In addition to the previously published and freshly created data, these specimens and their related pictures were examined and compared. A combined comprehensive and integrative taxonomy strategy using a broad comparative collection of morphological data and molecular approaches was used to concentrate specifically on japonicus-group species from the SWIO and neighbouring locations. Specimens from seven locations in KwaZulu-Natal, South Africa, and three locations in Mozambique were used to define the new species of Upeneus floros n. sp. Additional U. pori specimens have been discovered off the coast of Madagascar. In interspecific comparisons, the new species is compared to U. pori and U. guttatus, which are both closely related to and co-occur with the new species in the SWIO. There are also in-depth comparisons between the five SWIO japonicus-group species and a summary of the most essential diagnostic features for all species in the japonicus-group. The findings are examined in light of the need for more research on goatfish distribution and abundance in the SWIO area, as well as the species' biology and ecology in light of the region's unique and complicated oceanographic circumstances.

2. THE GOATFISH UPENEUS NIGROMARGINATUS, AN ENTIRELY NEW SPECIES (PERCIFORMES: MULLIDAE):

Mullidae goatfish have an elongated body with two independent dorsal fins and two unbranched barbels on the chin that distinguish them from other goatfish. There are six genera and 83 species in this family. The genera Mulloidichthys, Parupeneus, and Upeneus, which together include 41 known species, dominate the western Pacific Ocean. It's possible to tell these three genera apart based on their inter-dorsal fin scale row counts and the number of lateral line scales on their dorsum. Mulloidichthy, Parupeneus, and Upeneus all have three inter-dorsum fin-scale row counts while Parupeneus and Upeneus have five to seven inter-dorsum fin-scale row counts, respectively. Generic classification may be aided by teeth's existence and form. The vomer and palatine teeth of Parupeneus and Mulloidichthys are missing. In Parupeneus, the teeth on the oral jaws are conical, but in the other two genera, the teeth are villiform.

There are 30 known species of Upeneus in the globe, with 11 of them being found in the Philippines. Twenty-five of the twenty-six Upeneus species found in the Indo-Pacific were divided into four distinct groups by Uiblein & Heemstra (2010). Based on combinations of the number of dorsal spines (VII or VIII) as well as the number of pectoral fin rays (13–17), the presence or absence of bars on the caudal fin, these groupings have been categorised.

2.1 A new species group of goatfishes has been discovered via taxonomic and genetic research:

Within large genera with a large number of species, it is standard practise to seek to group species together based on the similarity of just a few clearly identifiable physical traits. This approach simplifies the process of comparing species within a genus and establishing identification keys, yet it cannot be used to infer evolutionary links with confidence. In order to evaluate if previously constructed species groups are valid representations of evolutionary links or whether they should be reassembled or split into other coherent units, comparative studies including a broad variety of morphological and genetic features are required.

There are presently 37 species of goatfish in the genus Upeneus, and past taxonomic investigations have identified five primary groups of traits that may be distinguished amongst them. It is worth noting that this group of fishes, the vittatus, differs from the others in that it has a greater number of pectoral-fin rays, gill-rakers, and lateral-line scales, as well as multiple dark-oblique bars on each of the caudal fin lobes, all of which will be discussed further in this article. For some time, the stenopsis group has been recognised as different from the vittatus group due to the absence of body stripes, the presence of a deeper caudal-peduncle, and the presence of a larger head and eyes.

Currently, science is aware of all five species of the vittatus genus, including U. indicus, U. parvus, and U. suahelicus. All of these species have yellowish body stripes and black bars on both caudal fins, as well as dark points on the first dorsum of the first caudal-fin lobe on the first dorsum of the first caudal-fin lobe. The morphometric traits of the U. suahelicus and the U. supravittatus were particularly similar in Uiblein and Heemstra's original study, although the other three species were more readily distinguished by morphometric characteristics. A longer barbel or varied colour patterns on the anal-fin origin of U. indicus, but U. parvus has a longer barbel or distinct colour patterns according on the species (strong size variation among both the lower caudal-fin lobe bars and their pale interspaces in U. vittatus). With the exception of U. parvus, the four other species are all known to occur in the Western Indian Ocean region (WIO). U. vittatus and U. supravittatus may both be found in the Indo-Pacific, off the coast of East India and the Eastern Indian Ocean, and both are considered to be invasive species (EIO).

Additional study data and photographs of freshly discovered individuals have recently been received for the vittatus group of WIO species, enabling for more detailed phenotypic comparisons to be made across a broad range of morphological and colour traits. Furthermore, barcoding was employed to investigate molecular differentiation and genetic links among a large number of Upeneus species in addition to the alpha-taxonomic investigation. There were no genetic samples of U. indicus available for this investigation.

We are able to (1) identify the so-called "suahelicus" group based on these findings, and (2) further study these discoveries using genetic approaches, thanks to revised taxonomic diagnosis and comparisons. The species of Suahelicus may be distinguished with the use of a key. Taxonomic and genomic barcoding investigations may be able to identify between species with differing degrees of evolutionary variety; nevertheless, there are benefits and downsides to using this method, as discussed below.

3. STRUCTURE, FUNCTION, AND ECOLOGY IN THE GOATFISHES:

ORSO groups of percoid fishes are distinguished by small structural differences in most instances. There are few notable exceptions to this general trend, including the goatfishes (Mullidae). Among their many specialisations are the hyoid barbels, which are unique among percoids, as well as a variety of other structural and functional traits. The adaptations seem to have been effective, since goatfishes can be found across the world's oceans, frequently in enormous numbers. The primary distinctions between the six otherwise very similar genera of the family are in dentition, which suggests a slight adaptive radiation based on the exploitation of barbels for diverse forms of eating.

Adult goatfishes have two well-developed barbels. In each pair, both members of the pair are able to move freely and have a variety of senses. Inactive goatfish tuck their barbels back beneath the chin and gill cover rims. Feeding is accomplished by lowering the barbels so that they rest on the water's surface just below the fish's bottom line. It's safe to say that all goatfishes utilise their barbels to detect prey that's just above or below the surface of the substrate (Figure 1). Goatfishes use a variety of strategies to catch prey when they find an environment that has these components. Barbels are used by certain animals, such as the Upeneus tragula as a digging tool (see also the comments of Hiatt and Strasburg concerning Parupeneus cyclostomus). In the state of Hawaii, Parupeneus cyclostomus (previously P. chryserydros) uses its barbels to penetrate holes and cracks in hard surfaces to free tiny creatures from their hiding places. An item detected by the barbels may be "blown" away by the Mulloides fiavolineatus (Mulloidichthys auctorum auctorum) to reveal it; the same species may also use its snout to dig into the sand to recover a food item (pers. obs). (Hobson, pers. comm.). Mullus surmuletus sometimes uses its snout to plough into the mud when eating, and while doing so, it expels water from its mouth.

All mullids, including goatfish, have been shown to lay pelagic eggs, larvae, and juveniles; only mature goatfish utilise these feeding strategies. The Mullidae's strong link between structure, function, and ecology is shown by the usage of their barbels and functionally connected features. It is possible that the uniqueness of the family has disguised evidence for the Mullidae's link to other percoids, which has not been particularly effective in determining this relationship. Beginning with the barbels, this paper explores the several

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unique characteristics of goatfish. When feasible, the functions of these peculiarities are compared to analogous developments in other teleosts. The study concludes with a discussion of mullid genus, family connections, and ecology. All six mullid genera represented in the University of Michigan's collections served as the basis for this article's research.

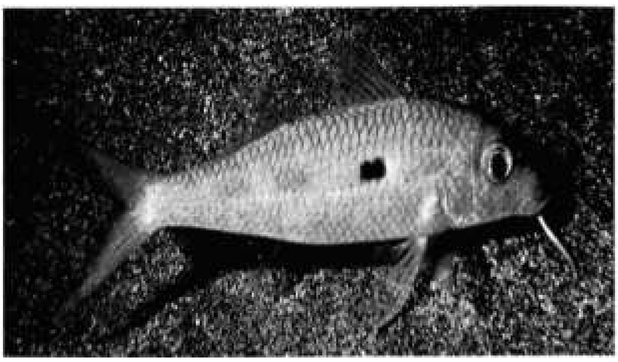

FIGURE 1. Probing for food by Mulloidesflavolineatus (Kona, Hawaii)

FIGURE 2. Upeneus tragula digging using its barbels (Ujung off Pandang, Sulawesi, formerly Makassar, Celebes)

Randall proposed the scientific names used in the report March 4, 1984). The following name changes are cause for concern: To replace the more often used genus name Mulloidichthys, Mulloides has been accepted as a legitimate alternative to Parupeneus chryserydrosis and in the synonymy of P. cyclostomus and U. taeniopterus. The topic of whether or not the closely related Pseudupeneus genus should be synonymized with Parupeneus remains unanswered.

4. HIDDEN TOOL IN GOATFISH TAXONOMY: THE OTOLITH MORPHOLOGY FEATURE:

In marine and brackish environments, goatfish (Teleostei, Mullidae) are mostly benthivores that reside above sandy to muddy bottoms and coral reefs. They may be found in tropical, subtropical, and temperate ecosystems between the upper littoral and the higher slopes of the oceans across the globe. Some of the world's most commercially significant species of goatfish may be found along the coasts. Because of their sensitivity to human-induced activities like fishing and habitat change, these fish are essential for ecosystem monitoring and management. As a result of their abrasive foraging activity, they churn up sediments and debris particles high in the water column via their barbels and mouth.

Only three genera and ten species are known from the Persian Gulf and the Gulf of Oman, out of a global total of 97 species and 97 genera. Adults have a pair of well-developed long chemosensory barbels on their chins, as well as a deep body, forked caudal fin, and widely spaced dorsal fins. Fish use their chemosensory barbels to locate food that is just above or below the substrate's surface. There are several species of goatfish, but the biggest (the dash-and-dot; Parupeneus barberinus) may grow up to 550 millimetres in length and is prized for its meat all over the globe. Also noted for their physical diversity are goatfishes. The number of gill rakers, fin rays, and vertebrae, as well as other morphological and meristic characteristics (such as body size, body colouring, head form, otolith shape, and scale ornamentation), have all been observed to vary across species and within species. Despite this, little is known about these fishes' core systematics and taxonomy, and more information may be found in their morphological characteristics. New species are continuously being discovered, and more research is needed into intraspecific variation and genetic differentiation. Using information on otolith morphology, researchers hoped to be able to tell between Persian Gulf and Gulf of Oman mullets. The Persian Gulf and the Gulf of Oman's fishes may be genetically distinct, according to a new study. Because of this, we study the otoliths in various marine habitats to see whether they vary qualitatively across species.

4.1 Otolith:

Hard tissues in the inner ear of every teleost fish, the otoliths, act primarily as a balancing organ and also help with hearing. Sagittae (the biggest pair), lapilli (the second largest pair), and asterisci (the third largest pair) are all constituted of of calcium carbonate ($CaCO3$). However, it is not always the case that the otolith structure grows in all three dimensions equally. In addition, the size and form of each species varies greatly. The biggest otolith (saccular) is known to be taxon-specific due to its different overall shape. The word "otolith" refers solely to the saccular otoliths in the following text.

Long before they were used to study paleodiversity, otoliths were used to study fish biology, trophic ecology, phylogenetic relationships, biogeographic distribution, fish stock identification, and the characterization of local populations. Otoliths are now being used to study these and other aspects of fish biology. Also, otoliths are used by fish, seal, and seabird biologists, as well as taxonomists and archaeologists, to evaluate fish biodiversity and to reconstruct the species and size compositions of the food of fish predators and to identify certain developmental phases.

Just a few papers have examined goatfish otoliths, including those Reunion Island and Mauritius Island juvenile yellow striped goatfish (Mulloidichthys flavolineatus) were studied by Pothin et al. (2006) using otolith morphometrics to distinguish between the two populations. The otoliths of the freckled goatfish Upeneus tragula were examined by Pavlov et al. (2012), who discovered that the lapillus had an irregular rhomboid form and the asteriscus had a triangular shape with rounded edges. Additionally, otolith morphometrics and ultrastructure were used to compare and distinguish three goatfish species from the northern Red Sea.

5. HAWAI'I'S MULLOIDICHTHYS SPP. JUVENILE GOATFISHES IN HISTORY AND THEIR FISHERIES:

Fishing is an important part of the Hawaiian way of life, both in the past and in the present. Only 1% of commercial fish landings in Hawai'i come from nearshore species, including as halibut, king mackerel, and halibut. On the other hand, the estimated 200,000-400,000 non-commercial fishers in Hawai'i, as opposed to the 3715 registered commercial fisherman in 2015, are expected to higher than their commercial counterparts, with a nearshore catch. Despite the importance of ocean resources to this island state's social, economic, and cultural life, many fisheries lack adequate data. Another well-known example is the widely practised nearshore fishing for young goatfishes (Mullidae; locally known as oama).

Mulloidichthys flavolineatus and Mulloidichthys vanicolensis, the yellowfin goatfish, are the most frequent goatfishes in Hawai'i. Small groups of this species' juveniles congregate year-round in shallow, nearshore regions in the major Hawaiian Islands (MHI), from marinas and canals to sandy bays and coral reef beds. This species is prized by local fisherman for its delicacy, as well as for its use as bait to attract bigger sea predators like jacks. However, there is a lack of scientific understanding on these species' life histories and biology despite their abundance and significance to fisheries and ecology. However, because of their cultural significance, significant traditional and local ecological knowledge, as well as grey literature and anecdotal material in the popular press, is available to the general public. Oama fisheries management is primitive, as is the situation for many other Hawai'ian coastal fisheries. For example, the present bag limit of 50 fish per day applies solely to M. flavolineatus while fishing.

In Hawai'i, practically all of the study on goatfishes has been conducted on the adults alone. Few researches have been done on the recruitment and early life cycles of spawning fish. Juvenile goatfish recruitment, as well as adult goatfish reproductive growth and spawning, are not well understood. The juvenile stages of these two species do not seem to interact or vary, despite the fact that they appear to have comparable recruitment traits. The environmental preferences of various goatfish species vary significantly, which is an obvious gap. Fisheries management and ecology benefit greatly from an understanding of fish species' early life histories. This is especially true for M. flavolineatus and M. vanicolensis, which are often targeted by nearshore fishermen with hook and line throughout their post-recruit juvenile phases. Fisheries management also plays an important role in identifying crucial recruitment habitats, particularly when they are occupied by nursery habitats at specified, distinct periods of the year. Because of the goatfishes' regular recruitment patterns, it is possible to examine their early life cycle traits in great detail.

6. CONCLUSION:

Upeneus species may be better understood by integrating alpha-taxonomy and barcoding in a mutually beneficial method to better comprehend their distinctness and relatedness. Alpha-taxonomy uses vast comparative datasets to develop similarity; in contrast, barcoding looks at evolutionary gaps in order to (re-)assemble species into phenotypically and genetically coherent groups. A limited number of species were targeted, but this strategy might be used to a broader range of populations and types of organisms. Interspecific and intraspecific variety, morphological as well as genetic variation in newly formed groups must be thoroughly investigated to have a better knowledge of species genera like Upeneus' evolutionary divergence.

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