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Example of Sexual Dimorphism and Structural Defects in Some Aquatic Insects (Coleoptera)

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ABSTRACT

Freshwater is a very important part of the ecosystem. Aquatic insects are at the center of importance of fresh waters due to their remarkable number and diversity.. The purpose of this study was to compare the morphological differences in male and female individuals with the arithmetic mean of some body measurements and to give a summary of rare unexpected structural disorders. On observing sexual dimorphism, *Helophorus aquaticus* Linnaeus, 1758 (Coleoptera) specimens were selected from the samples collected from Erzurum Wetlands (Turkey) between April and October (2021), as it has a large body and their number in the collection was sufficient. Measurements were performed under a stereo microscope. In this context, some differences in measurements were evaluated by considering sexual dimorphism, some structural disorders and gender-developmental stages in our study. Along with some ecological data, like sexual difference of approximately 100 samples, measurement differences were identified with body length 0.1-0.4 mm, body width 0.1-0.3 mm and leg length 0.1-0.3 mm. There are differences in measurements between the two groups, and in some species belonging to some families of the other Coleptera order, individuals with structural disorders have been identified.. It is believed that the developmental stages and sexual dimorphism size differences are important data for future ecological and evolutionary studies.

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Bazı Sucul Böceklerde (Coleoptera) Eşeysel Dimorfizm ve Yapısal Bozukluklar Örneği

ÖZET

Tatlı sular ekosistemin çok önemli bir tamamlayıcıdır. Sucul böcekler sayı ve çeşitlilik açısından dikkat çekmeleri nedeniyle tatlı suların önem bakımından merkezindedir. Bu çalışmanın amacı; erkek ve dişi bireylerde morfolojik farklılıkların bazı vücut ölçülerindeki aritmetik ortalamasıyla karşılaştırılmasını sağlamak ve nadir karşılaşılan beklenmedik yapısal bozukluklara önek vermektir. Eşeysel dimorfizmi görebilmek için; Erzurum Sulak alanlarından (Turkey) nisan ve ekim ayları arasında toplanan örneklerden büyük vücuda sahip olması ve toplanma sayısı yeterli olduğu için *Helophorus aqauticus* Linneus, 1758 (Coleoptera) türü seçilmiştir. Bir stereo mikroskopta ölçümleri yapılmıştır. Bu bağlamda; ölçümlerdeki bazı farklılıklar çalışmamızda eşeysel dimorfizm, bazı yapısal bozukluklar ve cinsiyet-gelişim evreleri dikkate alınarak değerlendirilmiştir. Bazı ekolojik verilerle birlikte yaklaşık 100 örneğin eşesel farklılığı olarak; vücut uzunluğunda 0,1mm.-0,4 mm., vücut genişliğinde 0,1 mm.-0,3 mm. arası ve bacak uzunluğunda 0,1 mm.-0,3 mm. arası ölçüm farklılıklarının olduğu, diğer Coleptera takımının bazı familyalarına ait bazı türlerde ise yapısal bozukluk örneği görüldüğü bireyler tespit edilmiştir. Sonuçların, gelişim evreleri ve eşeysel dimorfizm boyut farklılıklarının gelecekteki ekolojik ve evrimsel çalışmalar için önemli veriler olacağına inanılmaktadır.

Zooloji

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INTRODUCTION

Freshwater ecosystems provide several functions for both nature and society. Freshwater affects biogeochemical processes, ecological dynamics of biodiversity, ecosystem productivity, and human health and welfare at local, regional and global scales (Albert et al., 2021). Freshwater insect abundance needs to be evaluated cautiously in the context of distinct (Jähnig et al., 2020) and morphometric characters.

Dey (2007) suggested that morphometrics can play a very important role in understanding some of the unique features and additional information about insects. Geometric morphometrics is a relatively new technique that has generated valuable results in the study of insects and ecology. The advantage of a geometric framework is comprehensive use of information about shape (Vijayakumar and Jayaraj, 2013). Because insects have morphometric variations, geometric morphometry has an important role in studying aquatic ecosystems. Study of morphometrics is a simple and quick technique, with low cost and very good discriminatory power. Also, Zelditch et al. (2004) mentioned that this new information from geometric morphometrics for biologists is divided into three parts topically: basics of shape data, analysing shape variables, and applications of morphometric methods.

Sexually dimorphic organisms provide elegant comparative systems in which to study adaptation (Dawson and Geber, 1999). The comparison of anatomical features of organisms, and understanding how variation in these features is associated with variation in other traits, has long been of interest to ecologists and evolutionary biologists (Adams and Castillo, 2013). Additionally, geometric morphometrics can be used in a phylogenetic context (Monteiro, 2013).

Finally, invasive species are well known to impact many aspects of ecosystems, including biodiversity (Li et al., 2021). Helophorus spp. insects are abundant in freshwater (Bektas, 2015). For morphometric aims, some measurements of geometrical features of aquatic insects, shape variation and descriptions of numerous functions are obtained as both two-dimensional and three-dimensional data (Adams and Castillo, 2013).

MATERIAL and METHODS

Collection of samples

One species of *Helophorus aquaticus* Linnaeus, 1758 (Coleoptera: Helophoridae) was used as a model (Fig. 1). Adult individuals of *Helophorus* spp. species and other aquatic coleoptera were collected from a randomly selected area of Erzurum Wetland (Turkey) from April-October 2021, using aerial nets in the late afternoon (Table 1). After the collected individuals were sorted and examined in using a stereo microscope (Zeiss Stemi 305) in the Entomology laboratory (Agricultural Faculty of Ataturk University) and East Anatolia High Technology Application and Research Center (DAYTAM) laboratories (Ataturk University), they were separated to two sections according to use in research. Then they were scanned, measured and parameters were calculated under light microscopy. The materials (hexapod) were stored in small bottles. The hexapod was cleaned with a brush before identification, and then the adeagophore of the hexapod was dissected under a stereo microscope in the laboratory. Bektaş (2015) was used for morphological identifications. The sampling time was not a special time, but a rain-free day when the insect could be in the adult phase. Also, the coordinates of localities (different sampling-points of Erzurum wetland) where the insect samples were taken were obtained by using a GPS device (Garmin Gpsmap 66S Handheld).

Figure1. Sexual dimorphism at *Helohrus aqauticus* Linneus, 1758 (Coleoptera: Hydrophilidae).
Şekil 1.*Helohrus aqauticus* Linneus, 1758 (Coleoptera: Hydrophilidae) türünde eşeysel dimorfizm.

Methodology

Every metric has the possibility to clearly contribute

to understanding (Daan, 2005). Aquatic ecosystem analysis was considered the aim of this study. The differences between males and females in morphometric measurements were tested using statistical analysis under stereo microscopy (Zeiss Stemi 305). To visualize the shape (Fig. 2 and Table 1), maximum and minimum values and variation coefficients were calculated using mean values and standard deviations. Measurements used the technological device which was located at DAYTAM. Additionally, the difference between measurements of morphometrics for male and female structures and structural defects may be an important focus in evolutionary research. Approximately 100 aquatic insect specimens (43 males; 54 females) of *Helophorus aquaticus*, were caught. This species was chosen because it is found in abundance by chance. Moreover, sexual dimorphism (in terms of size) is evident and body size is easy to measure. Other aquatic insects with structural defects were found by chance and the insects were photographed to make use of this opportunity (Fig. 3).

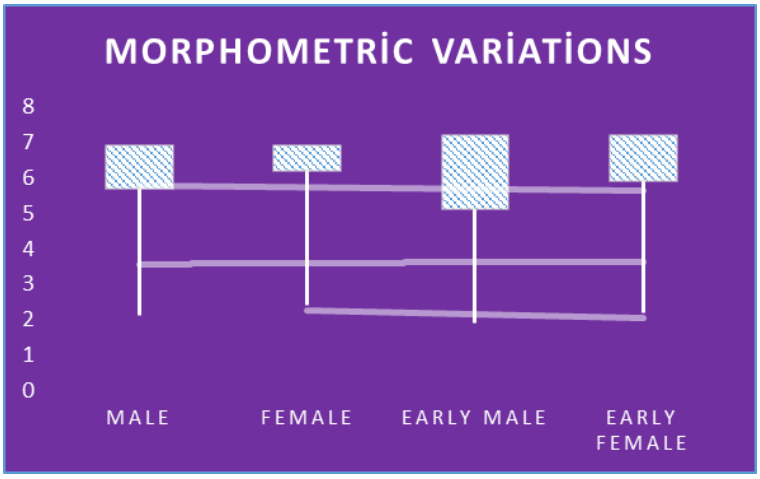

Figure 2. Morphometric variaons on stage and sexual of collected *Helophorus* spp. species.
Şekil 2. Helophorus spp. türlerinde yaşam evreleri ve cinsiyetlerine göre morfometrik varyasyonlar.

Table 1. Morphometric scales on *Helophorus aqauticus* Linneus, 1758 (Coleoptera: Hydrophilidae) species.
Çizelge 1. Helophorus aqauticus Linneus, 1758 (Coleoptera: Hydrophilidae) türünde morfometrik ölçümler.

Gender	Collected Information	Body Length (mm)[a]	Body Width (mm)[a]	Leg length (mm)[a]	Freshwater temperature (°C)[a]	Freshwater pH*
Male ♂	Coordinates: 39°58'02.0"N/41°17'52.5"E Location: Vegetation Regions, Local Conserved Wetlands. Erzurum Wetlands, Turkey Collected time: April-October	5,7±0,1	2,1±0,1	3,5±0,1	25±1	6.9±0,1
Female ♀	Coordinates: 39°58'02.0"N/41°17'52.5"E Location: Vegetation Regions, Local Conserved Wetlands. Erzurum Wetlands, Turkey Collected time: April-October [b]	6,2±0,1	2,4±0,1	3,8±0,1	25±1	6.9±0,1

[a]Average measurements
[b]There are twin sercus at last sternit of abdomen

Figure 3. Structural defects at some aquatic insects (Coleoptera).
Şekil 3. Bazı sucul böceklerde (Coleoptera) yapısal bozukluklar.

RESULTS and DISCUSSION

The most conspicuous secondary sexual traits in animals are morphological features. This is exemplified by body size in insects (Ariza-Marín and Luna, 2022). In past research, populations of insects confirmed that morphological traces were not more structured than genetic patterns and did not always correlate (Zubrii et al., 2022). Also, teratology (structural defect) studies the causes that produce structural malformations, defects or abnormalities in organisms (Burke et al., 2018). Before genetic support, insect studies are needed to reveal morphological differences and obtain preliminary data. These analyses were conducted for both structural defects and morphometric differences. Here we attempt to demonstrate that utility of morphometric and structural analysis as a new methodology for research. Also, there are some groups that are:

For animals, some anatomical structure appears to be good markers of quality of diet, with feedback mediated by sex (Gutiérrez-Cabrera et al., 2022). Insects are among the most successful animals among species in the world. Their success is partly attributed to their modified, sclerotized forewings, known as elytra, that protect their body against physical damage, desiccation, predation and thermal stress, enabling them to occupy a wide range of ecological habitats (Katlav et al., 2021). An increase in insect abundance may reflect improved water quality (Jähnig et al., 2020), as distribution and behaviour of insect populations are based on their powerful structures and adaptation to the environment. Wings, legs and genital organs are excellent structures for studying morphological variations. Comparisons of results among these studies are difficult because of the different morphometric methods and concepts of modularity and integration (Joji´c et al., 2012). Morphometrics is defined as the quantitative description, analysis and interpretation of shape and variation of structures in biology (Mondal et al., 2015). As in other applications of geometric morphometrics, some adjustments may be needed (Klingenberg et al., 2003). Plus, these studies contributed to resolving taxonomic problems in aquatic insects and other species (Petrarca et al., 1998). Dawson and Geber (1999) indicated that females are more often limited in their reproductive success by resources, whereas males are limited by opportunities for mating. Consistent with this view is the very strong evidence of larger resource (biomass) investments in reproduction in females compared to males. This approach may be supported for aquatic insects. Morphological integration also manifests at a macroevolutionary level (Klingenberg, 2008). It is important to study teratomorphs because they can last a long time and manifest in the phylogeny of a certain lineage; also these morphological abnormalities pinpoint the underlying genetic determinism of the morphology. Morphological anomalies are not uncommon in insects, and Coleoptera is one of the orders with the highest number of described teratological cases (Popa et al., 2021). Therefore, it is very important to find these teratological images in our morphometric and ecological studies of aquatic insects.

Some differences in animal body shape arise even when there are minimal variations in diet (Huie et al., 2020). A similar study (Almeida et al., 2021) found females were larger than males in body length, but males had thicker arms and forearms. The diet of males and females is similar for *Hylodes perere* Silva

& Benmaman, 2008 (Anura, Hylodidae), comprising insects, arachnids and crustaceans, suggesting a similar foraging strategy for both sexes. Francoy et al. (2009) examined the forewing venation patterns of males and females of five stingless bee species and reported that the patterns of males and females from the same species were more similar than the patterns of individuals of the same sex from different species. They suggested that the features extracted from the wings of males and females were very informative in discriminating the five species. Metrics, however, measure something specific, while indicators are supposed to tell us something different from what they actually measure (Daan, 2005).

Above all, the analyses showed that there was strong integration of geometric morphometric analysis, and that this approach might help future studies not only by contributing to solving problems in systematics but also in understanding the flight mechanism of bumblebees (Aytekin et al., 2007). Klann et al. (2021) performed on study of sensory mechanisms that cause severe structural defects on sensilla pattern in *Tribolium castaneum* larva (Tenebrionidae). Moreover; a study of an insect species belonging to the Pentatomidae family found correlation between sexual dimorphism and epicuticular hydrocarbon. Differences were found in the epicuticular hydrocarbon pattern among nymphs and adults, as well as sexual dimorphism in adult stink bugs (Sessa et al., 2021).

The most common hypothesis is that females are larger than males and this is prevalent in many animals (Kelly et al., 2008). Instruments of geometric morphometrics will be able to answer many specific questions about evolutionary diversification of shape. A foundation of other multivariate methods can also be used in a comparative context to understand geometric morphometrics and structural defects (Revell and Harmon, 2008). Results show:

Since it was invented, the microscope has become very important to investigate microinvertebrates and macroinvertebrates, especially insects. With the development of technology, microscopes have been developed for scientific research. This search has progressed with the ability of the researcher to observe tiny organisms.

So we undertook a comparative study of correlations of morphologies for male and female body structures, such as body length in approximately 100 aquatic insects (43 males; 54 females) in the genera *Helophorus*. *Helophorus* spp. includes aquatic insects, distributed in a wide habitat, that were collected from Erzurum province in Turkey. In this genus, morphometric characteristics are vital for understanding how organism shapes evolve. Additionally, comparative studies are necessary due to the identification of specific data about structure. Studies that emphasise the variability in body measurements are very useful for identification and ecological dynamics.

The results showed that both male and female insects have different measurements. Additionally, sexual dimorphism may be an important force with ecological dimensions based on measurements of morphometrics of male and female organs. There is no inherent limitation in phylogenetic comparative approaches that restricts them to regression. On the contrary, all the usual tools of geometric morphometrics can be used in a phylogenetic comparative context (Monteiro, 2013). Similarly, it is unsurprising that insect structural defects are explained by their necessary generation as a function of local area variation in related tissue and cells (Kim et al., 2016). When viewed in this light, the approach described here provides a general conceptual framework for understanding patterns of change in morphometrics. Our results may indicate that differences in sexual dimorphism between these *Helophorus* insects could be due to differentiation of developmental methods and possible distinctions of feeding activity between individuals. It is believed that further investigations are needed.

CONCLUSION

These methods are mathematical applications of geometric morphometric. Geometric morphometry is a simple and quick technique with low costs, and revealed itself to be a valuable tool in this research. Distribution and behaviour of insect populations are based on their powerful structures and adaptation to the environment. Wings, legs and genital organs are excellent structures for studying morphological variations. This research is the first to demonstrate that a wide range of morphometric methods can be combined with morphological defects, which is concerned with structural changes. It is believed that these data will support the improvement of these new methods.

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Author's Contributions

The contribution of the authors is equal.

Statement of Conflict of Interest

Author has declared no conflict of interest.

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