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INVESTIGATING THE PRESENCE OF CLADOCERA SPECIES WITHIN THE WETLANDS OF UAE

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جامعة الإمارات العربية المتحدة
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College of Science

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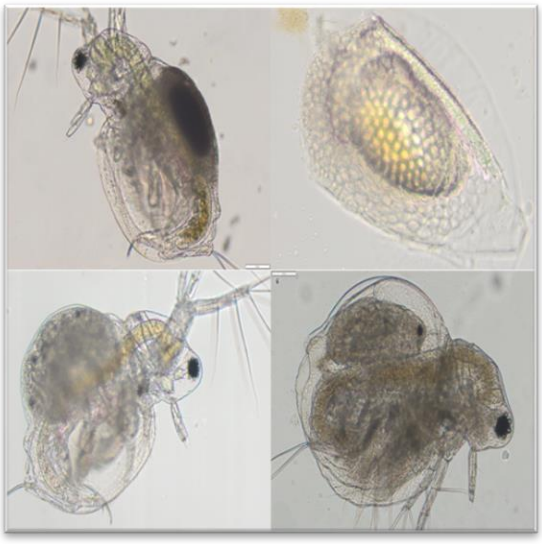

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental Sciences and Sustainability

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Declaration of Original Work

I, Shamma Eisa Salem Shahdad Alneyadi, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*Investigating the Presence of Cladocera Species Within the Wetlands of UAE*", hereby, solemnly declare that this is the original research work done by me under the supervision of Professor Waleed Hamza, in the College of Science at UAEU. This work has not previously formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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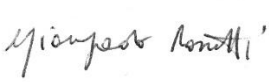
Signature  Date 4th. April 2022

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Abstract

The wetlands ecosystems found in the Arabian Peninsula have been poorly investigated. Moreover, the available information about the presence of freshwater communities have been rarely documented. Although there are scattered records about the presence of freshwater Cladocera organisms within the Arabian Gulf countries; few of them have received proper taxonomic identification. Cladocera populations in freshwater bodies are always characterizing its water quality and other living invertebrates' community. United Arab Emirates wetlands are among the ecosystems belonging to Ramsar convention for its conservation. The presence of both temporary and permanent freshwater area has been developed after the great interest to collect and use the rainwater across the country for replenishment of underground water that has been used for long time in many purposes. The aim of the study is to investigate the presence of *Cladocera* species within the wetlands of UAE. The study also aimed to find information about the dams in UAE and their locations at the different Emirates. In this study, ten (10) locations from different Emirates were chosen based on their accessibility. Samples were collected from both existing water and sediments of the selected locations. Hatching technique of the collected resting eggs followed the methodology described by Hamza et al. (2018) that resulted in the identification of different species. Three types of microscopes (Stereo, Compound, and SEM) were used in this study to identify the species, that is in addition to their Molecular identification. From the ten selected locations, five species were identified; two of them are new record for the UAE territory (*Moina Micrura*, *Ceriodaphnia cornuta),* two species of previous record in UAE by Van Damme and Dumont (2008) *Coronatella anemae,* Van Damme et al. (2011) *Anthalona mediterranea* and the fifth species (*Daphnia Similoides*) was mentioned by Hamza et al. (2018). However, this species is still not confirmed, since its molecular identification does not match with its DNA sequence found at the Gene data bank. The present study may be the beginning of new collaborations between the Arabian Peninsula countries in recording and investigating the presence of *Cladocera.*

Keywords: *Cladocera*, UAE wetlands, *Moina Micrura, Ceriodaphnia cornuta*, *Coronatella anemae, Anthalona mediterranea*, Taxonomic details.

Title and Abstract (in Arabic)

التحقق من وجود أنواع من الكلادوسيرا في الأراضي الرطبة بدولة الإمارات العربية المتحدة

الملخص

لا توجد دراسات كاملة عن البيئات الموجودة في الأراضي الرطبة بالجزيرة العربية، كذلك فإن المعلومات المتوفرة عن مجتمعات المياه العذبة قليلة وغير موثقة، مع العلم بأنه توجد بعض الأبحاث العلمية التي تشير إلى وجود أنواع من حيوانات الكلادوسيرا في أماكن تواجد تلك المياه العذبة، إلا أن هذه الأبحاث تفتقر الى التصنيف العلمي الصحيح لتلك الكائنات. وتمثل عوائل الكلادوسيرا في بيئة المياه العذبة مؤشرا على جودة المياه وكذلك على تواجد تجمعات أخرى من اللافقاريات. وتنضم مواقع الأراضي الرطبة بدولة الإمارات العربية المتحدة الى قاعدة بيانات معاهدة رامسار للحفاظ على بيئتها. وتشير معظم الأراضي الرطبة الموجودة في دولة الإمارات العربية المتحدة سواء كانت دائمة أو مؤقتة، الى حرص دولة الإمارات في الحفاظ على مياه الامطار، حيث انها المصدر الأساسي لتغذية المياه الجوفية والتي كانت ولاتزال تستعمل في الأغراض المختلفة. لذلك فإن الهدف الأساسي من هذه الدراسة هو التحقق من وجود حيوانات الكلادوسيرا في بيئات تلك الأراضي الرطبة في دولة الإمارات، وكذلك تحديد المواقع المختلفة للأراضي الرطبة في مختلف أنحاء الإمارات. وفي هذه الدراسة تم تحديد عشرة (10) مواقع على أساس إمكانية الوصول إليها. وقد تم جمع عينات سواء من المياه المتبقية أو من الرسوبيات الموجودة في تلك الأماكن. كما تم عملية فقس البويضات الموجودة في هذه العينات باستخدام التقنية المذكورة بالبحث (Hamza et al., 2018). وللتعرف على الأنواع التي ظهرت في تلك العينات عن طريق الشكل الخارجي تم استخدام ثلاث أنواع من الميكروسكوبيات (Stereo, Compound, and SEM) وذلك بالإضافة الى التحليل الجزيئي للحمض النووي لتلك الحيوانات. وبناءً على دراسة الشكل الخارجي والتحليل الجزيئي، فقد تم التعرف على خمسة أنواع، منهم نوعان يتم تسجيلهم في هذه الدراسة لأول مرة لرصدهم بأراضي دولة الإمارات (*Moina Micrura* and *Ceriodaphnia cornuta*)، ونوعان آخران قد تم تسجيلهما من قبل العالم (Van Damme & Dumont, 2008) والعالم (Van Damme et al., 2011). وقد تم التعرف على النوع الخامس والذي تم تعريفه بواسطة (Hamza et al., 2018) باسم (*Daphnia Similoides*)، إلا أن نتائج التحليل في هذه الدراسة تشير الى أن هذا النوع يختلف

في بعض صفاته الخارجية وكذلك صفات الحمض النووي مقارنة بالبيانات المحفوظة في البنك الجيني المتخصص لتلك الحيوانات. وتعتبر هذه الدراسة هي بداية للعديد من الأبحاث المشتركة في هذا المجال خلال السنوات القادمة بين الباحثين من دول الجزيرة العربية.

مفاهيم البحث الرئيسية: الكلادوسيرا، الأراضي الرطبة بدولة الامارات العربية المتحدة ، دراسة الشكل الخارجي،

Moina Micrura, Ceriodaphnia cornuta, Coronatella anemae, Anthalona mediterranea.

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Special thanks go to my parents, brothers, and sisters who helped me along the way. I am sure they suspected it was endless. In addition, special thanks are extended to my colleagues for their assistance and friendship.

Dedication

To my beloved parents and family

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List of Abbreviations

BCEAW	Breeding Centre for Endangered Arabian Wildlife
CWP	Clear-Water Phases
HB	Haemoglobin
IDL	Inner Distal Lob
MEW	Ministry Of Environment And Water
MOU	Memorandum Of Understanding
ODL	Outer Distal Lob
PH	Potential Hydrogen
QTL	Quantitative Trait Loci
RAK	Ras Al Khaimah
RAS	Russian Academy Of Science
SEM	Scanning Electron Microscope
SP	Species
UAE	United Arab Emirates
UAEU	United Arab Emirates University
WHO	World Health Organization

Chapter 1: Introduction

1.1 Overview

Cladocera organisms or as it's known as water fleas, are taxonomically ranked under the Phylum Arthropoda, subphylum of Crustacea, class of Branchiopoda, that means they breathe through feathery gills at the base of walking legs. Branchiopoda is a vary heterogenous group that share some characteristics such as same larva morphology, phyllopod which is the flattened thoracic legs, edges with setae, usually unbranched with no distinct segmentation with corrugated grinding inner surfaces (Dodson et al., 2010). It consists of four major groups; The first group is the Anostraca (fairy shrimp or sea monkeys), the second group Notostraca (tadpole shrimp), the third group is Cladocera (water fleas), and the fourth group is Conchostraca (clam shrimp) (Dodson et al., 2010). Cladocera are the most diverse taxon of Branchiopoda morphologically, and they have a lengthy history, considered to have existed since the Permian era (Martin & Cash-Clark, 1995). They became of high importance due to the latest studies on them regarding their evolutionary features that cover their ecological and morphological diversification. Cladocera's does not lays only on their importance as a study model but also as they have a significant effective role in the food web (Miner et al., 2012).

They are belonging to zooplankton communities in aquatic environments. They are transparent, fragile, and often have limited swimming ability. Their body size ranges from 0.2-3 mm with some exceptions in certain species. Their body is typically covered by two valve called carapace except the head which is not covered by the carapace. The carapace is used by the female Cladocera as brood chamber. It has no

segmentations for many species in this order. Moreover, their thorax and the abdomen are fused and covered by the carapace that give them a distinguished shape that looks like bivalved shaped. The Carapace is closed from the back dorsal side till the head and open from the ventral side so they can't groom the carapace and often if they did not mold the carapace covered by encrusting organisms in couple of weeks (Dodson et al., 2010). The head of Cladocera organisms has helmet like structure connected with the carapace and it is curved outward forming a beak like called the rostrum. The size and shape of helmet-like head varies from generation to another depending on the environmental condition that Cladocera faces; where sometimes develops a spine on the head of certain species (Ebert, 2005; Dodson et al., 2010). On the other hand, Cladocera has a unique movement pattern characterized as jumping and probably that is why they are called as "water fleas". This movement is produced by the stroke movement of the second antenna that is very well developed (Toyota et al., 2016). Cladocera's eyes characterized as a large sessile compound eye formed by the fusion of paired eyes and it can rotate in different direction (Glime, 2017). On their body there are 5-6 appendages on the tip of the trunk forms the post-abdomen. The post-abdomen is bent toward the trunk, and it has a claws and spines that help in cleaning the carapace. They have the ability of altering their appearance throughout the generation in response to the environmental conditions and that process is called cyclomorphosis (Dodson et al., 2010).

Cladocera is unique in its reproduction. They can reproduce both sexually and asexually (Figure1). Reproduction modes depend on the environmental condition such as food abundance, temperature, oxygen level in water, illumination and population crowding. However, the favoured mode of reproduction in Cladocera is asexually most of the time called the parthenogenesis/parthenogenetic reproduction. In the asexually

mode the Cladocera eggs develop in between the carapace in the brood chamber, and it take around two days until reach maturation. Asexually eggs that produced in favourable condition develop into young's immediately while in unfavourable condition, they produce an egg that can enter resting stage called the diapause egg (Winsor et al., 2002; Dodson et al., 2010; Fritsch et al., 2013). While in sexual mode a clone can be produced including male and female. Male mates with a female and the fertilization happen and it result in deposition of an ephippium (Zhang et al., 2016). These resting eggs are resistant to heat, desiccation, drought, freezing and most of the eggs develop into females. The occurrence of males is triggered by signals such as crowdedness, change of food concentrations and sometimes due to decreasing of day length (Dodson et al., 2010).

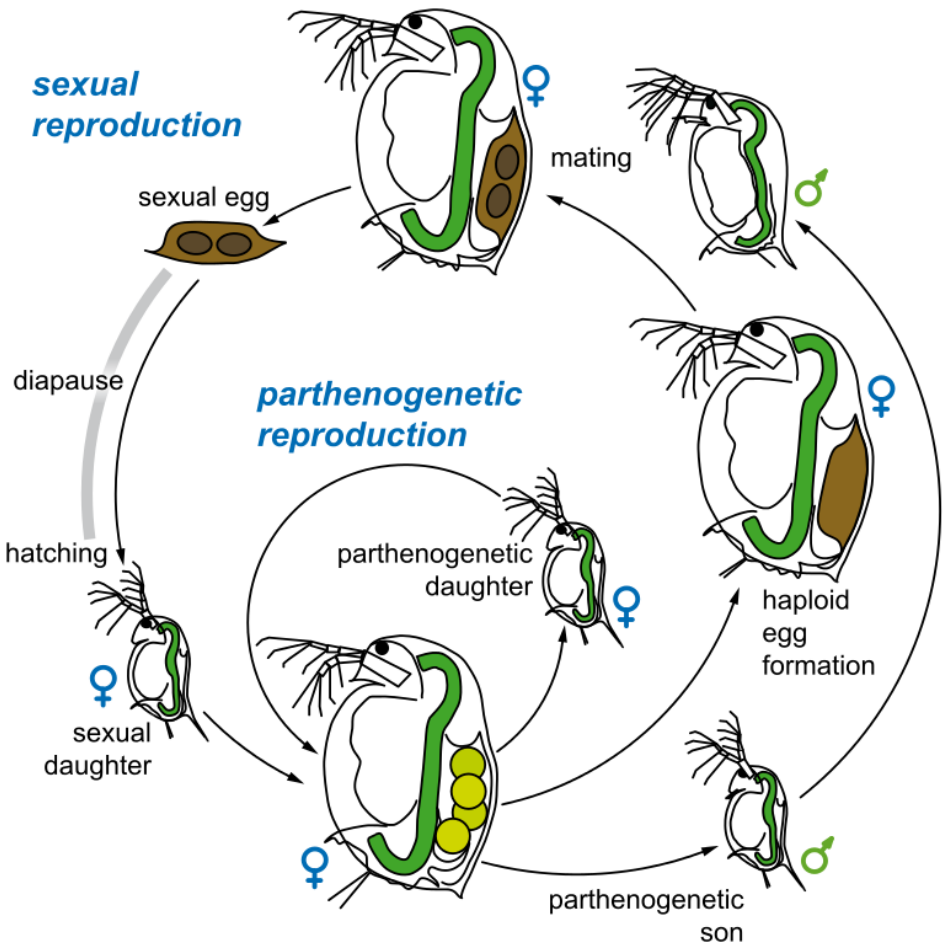

Figure 1: Cladocera life cycle (c.f. Dvizoso.svg, 2022.)

Cladocera, mostly found in freshwater habitats across the world, ranges from shallow temporary pounds, brine pools too deep lakes, slow-moving streams, reservoirs, ponds, canals, swamps, and large rivers. Also, they can be found in quiet water and marginal vegetation and in fast-moving streams. In addition, few species only inhabit brackish or marine water. They are widely distributed across the continents, they found from the Arctic to the Southern Ocean, from sea level to alpine ponds, as the case of *Daphnia magna* (Figure 2). Cladocera species group are either lives on the bottom sediments as benthic species or on the surface of macrophytes on aquatic vegetations or stones. They are phytophile, planktonic, forms the plankton community as algae grazer. They feed by filter feeding or by other variety of feeding strategies including scavengers or scrapers and predator which, is known as raptors. In the Cladocera order, most of the species eats bacteria, detritus, or algae but some are predators that feeds on other species such as *Leptorora sp., and Bythotrephe*s sp. In general, benthic Cladocera specially the filter feeders collect food from the surface of the substrata using their strong second thoracic antenna. The food which is collected in the groove at the base of their second antenna and mixed with mucus to form a bolus or mass is pushed toward the mouth. Then the excess water is removed by undulating the exopodites of their posterior limbs (Ebert, 2005).

Figure 2: *Daphnia magna* distribution around the world (c.f. The *Daphnia magna* diversity panel. Evolutionary Biology | University of Basel, 2022)

Surface freshwaters are unevenly distributed on earth, where permanent streams and lake are absent in some places and some countries suffer from excesses of water while other countries experience sever scarcity of freshwater such as the Arabian Peninsula which including United Arab Emirate (UAE). UAE is one of the Arabian Peninsula countries that is located within the aired zone that extended between Latitudes of 22˚ and 26.5˚ north and Longitudes of 51˚ and 56.5˚ east of Greenwich, north of the equator, in the tropical zone. It has an area of 83,600 km^2 and around 74% of its land is a desert while the northern region of the emirate has a variety of landscapes including mountains, valleys (Wadies), and flat coastal plains (UAE Annual Book, 2016). It experiences sever scarcity of freshwater, low rainfall, high temperatures and extreme evaporation rate (Alsharhan & Rizk, 2020; Hamza & Munawar, 2009). UAE is paying great attention to manage the water resources especially freshwater that coming from rainfall but with short periods of precipitation, which sometimes become intensive and cause floods. In that concern, the UAE federal governments, constructed dams to contribute to protecting the areas from the floods

and to capture the water of rainfalls to increase the feeding rates of groundwater (Al-Nuaimi & Murad, 2007). Although along the year, most of the basins of such dams are dry, some of those dams, such as Hatta Dam, has water along the whole year, because of its vicinity to Oman mountains. So, having areas with permanent freshwater and dams that have water either temporary or permanently have increased the chances of developing favourable habitats that allows the presence of Cladocera populations. Because of the absence of knowledge about the ecosystems of such freshwater basins at UAE and the little information available about the presence of Cladocera species within the Arabian Peninsula, the present study has been developed with the aim to investigate the presence/existence of Cladocera species within UAE territory. It also aims to identify and classify the species that found in the UAE dams' sediments or water reservoirs basins either with or without water. The classification will be based on both morphological and molecular characteristics of the collected species. Moreover, it intends to establish a guide to most of the UAE freshwater reservoirs and to locate them on a geographic map that, will be of help for future studies.

Chapter 2: Literature Review

Crustacean order of Cladocera is part of zooplankton organisms that are widely studied all around the world. They are mostly freshwater monophyletic group which, inhabiting freshwater ponds, lakes, and permanent water bodies, while some inhibits saline waters (Lampert, 1997; Mergeay et al., 2006). They are important as model organisms used for studies that testing developing ecological theories. In addition, it is important in both basic and applied research. Their importance came due to their easy culturing, short generation time and clonal reproduction (Forró et al., 2007; Miner et al., 2012). Naturalist and experimental biologists have been focusing on the genus of *Daphnia* for studies and research for about centuries. Studies of *Daphnia* focusing on their functional, morphological taxonomic classification, on their biogeography and on their unusual life mode (Ebert, 2005). *Daphnia* have been serving as an essential indicator for environmental problems (Ebert, 2005; Dorchin & Shanas, 2013). It has the ability of clearing the lakes water and controlling the algae blooming. Many studies have shown that *Daphnia* can graze phytoplankton more effectively than any other freshwater zooplankton (Villegas-Navarro et al., 1999). Also, the seasonal rise in water clarity caused by consumer–resource dynamics between *Daphnia* and phytoplankton, known as the ‘clear-water phase,' has a huge ecological impact (Wojtal-Frankiewicz, 2012). In a study done in six lakes related to Qu’Appelle Valley Canada (i.e., Diefenbaker, Buffalo Pound, Katepwa, Crooked lakes, Last Mountain and Wascana lakes) to figure out if Clear-Water Phases (CWP), is related to the grazer in lakes where *Daphnia* is the prior grazer. The research suggested that clear-water phases are the result of complex interactions between light, temperature, nutrients, and biotic interactions of plankton and their predators (Dröscher et al., 2008). The study proved

also that the selective grazing of *Daphnia* on siliceous algae is the primary driver of CWP growth in prairie lakes. Moreover, thermal stratification cannot explain reductions in diatom density during CWP development since all lakes are polymictic. Not only the presence of *Daphnia* but also the size of the grazer affects the productivity of phytoplankton (Dröscher, et al., 2008).

Large-bodied taxa graze at a faster rate than small-bodied taxa, with which they usually compete. Even within a *Daphnia* species, differences in body size can have distinct effects on plankton ecosystems. This indicates that *Daphnia* populations have a lot of phylogenetic and genetic diversity that enhance its ability to influence phytoplankton abundance and productivity. Moreover, *Daphnia* occupies a unique place in the pelagic ecology of many lakes due to its combined impacts on phytoplankton grazing and nutrient cycling, as well as its role as a favored prey species for secondary consumers. They have several features that make them ideal for genetic research (Shaw et al., 2008). The simplicity with which *Daphnia* may be managed and maintained in the laboratory is another practical feature that makes them an excellent model system for experimental research (Altshuler et al., 2011). These distinguishing characteristics enable researchers to use what they know about their population structure and ecology to the investigation of broad ideas that span biological scales and disciplines. Several of these characteristics based on their extensive life cycle that are cyclical parthenogenesis, where they may reproduce both clonally and sexually. Their genetic background can be kept constant thanks to clonal replication and allows for the preservation of permanent complete genotypes. Using clonal reproduction, researchers may compare different treatments against a known or predetermined genetic background (Hebert & Ward, 1972). Asexual production induces a fast population and a high frequency of female under favorable condition such as

abundance of food optimal weather condition and low perdition pressures. In this mode females tend to produce clones, of males if the condition is not favorable or due to high population density and females when the condition is favorable and the population maximized by asexual means (Onbé, 1985; Kiiskinen & Hakatie, 1993; Jia et al., 2018). Females produce genetically identical newborn during sexual reproduction leading to haploid sexual eggs. Sexual mating leads to fertilized egg (encased in ephippia). Diapause egg, that can be in the environment viable for several years and decades without hatching. A favorable condition after several years or months can help in hatching the resting egg (Shaw et al., 2008; La et al., 2014; Gerber et al., 2018; Jia et al., 2018). This allows inbred lineages to be established through genetic manipulation throughout crossing. It has been mentioned that *Daphnia* is an appropriate model organism for mapping and characterization of Quantitative Trait Loci (QTL) for complex characteristics due to their unique breeding system flexibility (Shaw et al., 2008). Interestingly some clone underwent some mutation leading to loss of sexuality producing resting eggs from a sexual mean alongside the production of male and female asexually (Koch, 2009). A study conducted by Gerber et al. (2018) using natural populations of *Daphnia magna* across their growing season concluded that sexual mode is usually occurring when asexual population growth starts to decrease due to high unfavorable conditions starts, and sexual frequency increased as the population of asexual density is high.

In addition, Cladocera have also gained a significant economic importance because of their widespread in aquaculture, and as a big filter-feeding planktonic species that have an indirect economic influence as significant fish food or phytoplankton-controlling species (Forró et al., 2007). As the demand of fish increased the aquaculture, business have flourished and the need of live feeding as well increased

leading to high economical demand of Cladocera as feed for aquaculture. *Artemia salina,* rotifer *Brachionus plicalitis* and the freshwater cladoceran *e.g., Moina micrura, Daphnia carinata* are the most often used live feed organisms in farmed fish and shellfish (Das et al., 2012). Gogoi et al. (2016) showed the importance of live food for many fish fry when they first start receiving exogenous feeding. The availability of live feed, particularly zooplankton in their habitat has connected to the performance of fish hatcheries. Cladocera's species used as live feed sources in larval fish rearing because of their increased nutritional content and economic feasibility of mass production. Due to their easily cultivation, they also gained economic importance in consuming algae and other debris that may accumulate in ponds and lakes, they can help to clean the water. In fact, they are water quality indicator organism that are utilized in water toxicity testing and the detection of various contaminants (Villegas-Navarro et al., 1999; Dorchin & Shanas, 2013).

Cladocera population survival and distribution around the world have controlled by several stressors and in some cases by specific parameters. There are numerous potential challenges that aquatic ecosystems may face, such as biotic and abiotic factors. Biotic factor or stressor such as competitors living animals or as predators. While, abiotic stressors, such as changes in food availability, reduction in dissolved oxygen concentration, pH variability, and dissolved organic carbon are example of stressors effecting Cladocera survival and productivity. On the other hand, Anthropogenic activities have been responsible for many changes in the environment such as pollution, climate change, increase of heavy metals concentrations, water salinity variations. All have led to the decline of the ecosystem's services, with sever impacts on freshwater ecosystems (Long, 2012; Cuenca Cambronero et al., 2018).

Studies showed that water salinity, pH and temperature variations affect Cladocera productivity and reproduction (Khudr et al., 2020).

A significant concern of salinity variations due to climate change that led to the intrusion of saline water into freshwater ecosystems (Liu & Steiner, 2017). Not only due to climate change but also because of anthropogenic activity such as introducing salt to the roads and lands washing with rain to lakes and rivers led to high salinity in nearby water bodies (Kaushal et al., 2005). A study done by Gonçalves et al. (2007), showed that long term exposure to salinity results of a significant reduction in reproduction and led to developmental delays and a reduction in the rate of daphnid growth. The study was done in two species of Cladocera (*Daphnia magna,* and *Daphnia longispina),* interestingly *D. magna* showed a higher tolerance than *D. longispina* to the high concentration of salinity. Halotolerance in Cladocera varies from species to another and it ranges from freshwater to saline water. Showing that *D. magna* has high tolerance to salt and can grow under the salinity stress but not as the optimal neutral condition they called Euryhaline while *D. longispina* is called stenohaline (Boronat et al., 2001).

pH is another stressor that affects Cladocera life cycle. Alibone and Fair (1981) studied the effect of low pH on *Daphnia magna* and they found that low pH may highly depress the oxygen uptake rate. The depression is due to the decrease in the ability of the gills to exchange oxygen dioxide with the surrounding medium because of a decrease in the oxygen dioxide diffusion gradient as a result of rising acidity, while pH levels, respiration in CO_2 free water appears to be unaffected. It has been mentioned that, in 1970 about 76% of species have faced a sharp decline due to the anthropologic activity that led to global warming which rose the temperature and affect about 50 % of freshwater ecosystems (Hallmann et al., 2017; Cuenca Cambronero et

al., 2018). Temperature effect was studied also by Khan and Khan (2008), they reported that, when the temperature rises above 16˚C, reaching around 22˚C the daphnids become more active. Their breathing and heartbeat rates increase as well as adapt to a lower body mass and smaller size. The higher temperature requires additional O_2 by increased rates of Haemoglobin (Hb) production, respiration, heartbeat, and other compensatory responses to hypoxia. As the metabolism increase, the food intake increases resulting in reduction of *Daphnia* size bodyweight. At 29˚C, the activity of cytochromec oxidase rose by 100 % when compared to 16˚C.That may imply that 29˚C is the upper limit for *D. magna* maintains their hyperactivity. Another study by Cuenca Cambronero et al. (2018), showed the effect of single stressor as temperature and two combined stressors as temperature and food scarcity on *Daphnia magna*. The outcome of this experiment concluded that as the temperature increase the mean size, age at maturity and the fertility decrease with no effect on mortality while, food scarcity resulted in reduced fertility, smaller size at maturity, and delayed maturation. Overall, the study, imply that under a global climate change scenario with high ecosystem production, the effect of high temperature on *Daphnia*, which is connected to greater metabolic needs, can be offset in part by high resource availability. High primary productivity, on the other hand, is often linked to eutrophication, which results in a shift from algae to cyanobacterial blooms, with severe consequences for higher trophic levels (Havens et al., 2016; Cuenca Cambronero et al., 2018).

Another study that combining more than one stressor showed that as the temperature increases simultaneously with the food the population of *Daphnia magna* increases but it decreased with the presence of cadmium. At higher temperatures, cadmium's negative effects on growth rate have amplified, but high food levels

shielded the daphnids from cadmium's negative effects (Heugens et al., 2006). External drivers Such as rainfall and runoff, wind, and temperature, as well as internal drivers such as bioturbation of sediments by fish and invertebrates can all have an impact on these proximal parameters. Climate plays a significant role in *Cladocera* life and distribution (Novichkova & Azovsky, 2017). Santos et al. (2018) stated that the distribution of microcrustacean in Brazilian semiarid region essential element in the temporal dynamics of limnological variables, whereas aquatic macrophytes have a significant influence in the geographical distribution of the microcrustacean assembly. So arid zones include drylands, and wetlands have many different parameters to define based on its characteristics such as rainfall scarcity, higher temperatures and evapotranspiration, lower humidity, and a general paucity of vegetation cover. It can be defined as arid, semi-arid and dry sub-humid areas the main distinguished characteristic of aridity is moisture. That means moisture and/or rainfall in this zone is somewhere below 600 mm/year, that made more of periodic seasons of drought and increase of heat (Malagnoux, 2007; Tchakerian & Pease, 2015). Arid regions are the world's most widespread fragile ecosystems, that covers around 30% of the world's land area, primarily between the Tropics of Cancer and Capricorn (Figure 3) (Warren, 1999; Tchakerian & Pease, 2015).

Water supply and replenishing of water bodies in arid areas is always happen during rainy seasons which characterized by a short period of rainy days usually low, unpredictable in summer period and normally for short duration (Al-Nuaimi & Murad, 2007). Sometimes it can be so intense causing floods and permanent water body such as lake, pools and ponds or it is collected behind dams.

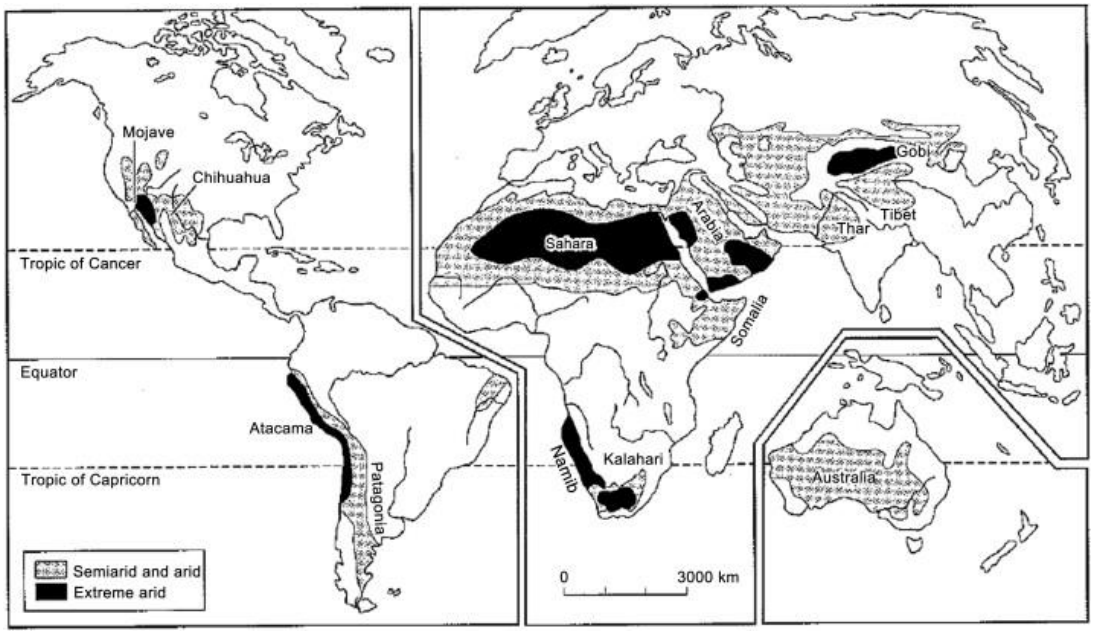

Figure 3: Map of World arid lands distribution (c.f. Tchakerian and Pease (2015))

Moreover, evaporation is another aspect of drought in the arid zones, where it is much greater than precipitation. High rate of evaporation in the arid zone may prevent the formation of waterbodies but it may develop short period non-permanent water bodies. An example of an arid regions in the world are dessert which can be found in the Sahara of North Africa, the Chihuahua and Sonoran deserts of Mexico and the southwestern United States, and the Gobi Desert and Middle East in Asia, which receives less amount of precipitation yearly and characterized by a hot dry climate most of the year. Arabian Peninsula is part of the Middle East, and it has vast land area that covers around 2,590,000 km^2. It is one of the driest parts of the world and it already passed water scarcity line as it was defined by the World Health Organization (WHO). The Arabian Peninsula is a desert region due to the extreme dry climate that has law precipitation of less than 100 mm/year (Tourenq et al., 2011). The fact that all the nations in the area are in dry and highly dry zones is an essential factor in the area's freshwater scarcity. Large variations in rainfall, limited renewable

groundwater supplies, increased groundwater salinity issues, and the lack of permanent freshwater bodies (Böer, 1997). United Arab Emirates (UAE) in particular, has no permanent streams or regularly recurring bodies of surface freshwater. So little precipitation does fall is drained from the mountains by seasonal wadis that lead to inland salt flats, or sabkhahs, which drainage is frequently blocked by the country's continually shifting dunes. Flash flooding is one of the characteristics of the area, mostly happen in the eastern UAE, and it usually accompanied with violent, short-lived rainstorms. Moving from the mountain's areas to the proximal end of watersheds and moves in wadis (valleys), fast towards the Gulf of Oman in the east or towards the desert in the west. On the other hand, the western regions lack of surface runoff due to low rainfall and high porosity and permeability of dune- forming sands. Majority of the wadis may remain dry for long periods (> 10 years), while others may only have surface runoff once every few years; But the major wadis may have many runoff events each year (Alsharhan & Rizk, 2020).

UAE government established dams and fixed the wadies roots to collect rainfall flood in the dams and keep the water for longer time to help the recharge of the ground water as well as a water resource. Wadis is a dry riverbed, and it is permanent or intermittent with rainfall water. The times that they do have water, wadis and dams are distinct to be considered as wetland ecosystems. That is because of their fast-developing ecosystems, which include temporary rainfall pools, bedrock and gravel riffles, and pools, that providing ideal nesting grounds for birds, foraging and breeding areas for amphibians, as well as for dragonflies and other aquatic insects or invertebrates. Most of wadis and dams are in the eastern region of UAE that characterized by Rocky Mountains, with high temperature where summer month's air temperature can reach up to 50˚C (Tourenq et al., 2011). The yearly rainfall ranges

from 40 mm in Liwa area to around 160 mm in the northern and eastern mountainous regions of the nation. Over the span of the year, precipitation falls between 9 and 19 days. During the winter, almost 80% of the yearly rainfall falls (December to March). Rainfall is uncommon in the spring (April–May) and is generally linked with rare thunderstorms (Böer, 1997). Rain is uncommon in the summer (June–September), and only happens because of afternoon thunderstorms over the eastern highlands or isolated thunderstorms following the occasional sea breeze fronts (FAO, 2008).

The eastern region wadis and dams mostly contain freshwater reservoirs, other lakes and water bodies that found in Abu Dhabi Emirate mostly salty lakes, salt flats, or sabkhahs. In Al-Ain City there is also wadis and some dams but they usually dry. The first spark of sustainability was in 1982 when the government started to move to fined root solution for water scarcity and how to reserve the rainfall water from being wasted in the sea (Alsharhan. & Rizk, 2020).

Water resource management has been undertaken on a large scale to avert significant problems that might arise in the future and disrupt water supply. Dam construction is a crucial step toward long-term water resource management and sustainability. There are two types of dams in UAE classified based on their materials of construction. They are either made of natural material found in the area called earth-type, (Earthen Dam), or concrete dams, widely used all-around the world (Kutzner, 2018). In UAE the Ministry of Environment and Water (MEW) build those dams mostly located and consternated in the eastern and northern part of UAE. Majority of those dams are of Earthen Dam (Earth-type) with two exceptions of which are concrete dams such as wadi Al Ghail in Ras Al Khaimah (RAK) and Gulfa in Ajman. These two dams have different cross-sectional area of the stream channel is narrow, while the other dams earth-type are built from readily accessible materials in plain location

shown in Figure 4 (Al-Nuaimi & Murad, 2007). Ham, Bih and Gulfa were the first three dams established in 1982 by the he Ministry of Environment and Water in the UAE. The total number of dams that was built by the Ministry of Environment and Water is about 114 dams until 2005, with carrying capacity of about 114, 146, 800 m^3 (Figure 5), (Al-Nuaimi & Murad, 2007).

Figure 4: Dam type in UAE, Wadi Al Ghail (RAK) (left), concrete type Hatta Dam (Dubai), Earthen Dam (right) (c.f. Google Maps)

Although Cladocera studies is widespread all over the world in the Arabian Peninsula those dams and water bodies ecosystems studies have done for water recourses and sustainability and rarely done for exploring the wadies and dams living biota, especially Cladocera. Cladocera investigations and discovery in the Arabian Peninsula may be rare or even not published. Macro-invertebrates' studies are recently published and becomes a topic of scientists' interest within the Arabian Peninsula research institutes. However, there is little research conducted on freshwater Cladocera water fleas. In Qatar for example the investigation of Cladocera in two waterbodies started in 2002 with no result or publications of any Cladocera. Kardousha (2017)

started another investigation searching for Cladocera in Qatar. He was the first to report the presence of Cladocera in Qatar taken from man-made wetlands and vernal pools. He found 24 species of micro and macroinvertebrate listed as 1 (one) Cladocera, 1 (one) copepod, 1 (one) notostaraca and 2 (two) ostracods.

No.	Name
1	Bih
2	Ham
3	Hadf
4	Zikt
5	Tawyyaien
6	Hatta
7	Shuaib
8	Shi
9	Warraiyaa
10	Gulfa
11	Eden
12	Gheli
13	Siji
14	Sufini
15	Burak
16	Shawkah
17	Dalm
18	Safad, Thyib
19	Ghalilah
20	Merbih, Kadfaa
21	Kidaa
22	Shaam
23	Ramth
24	Mai

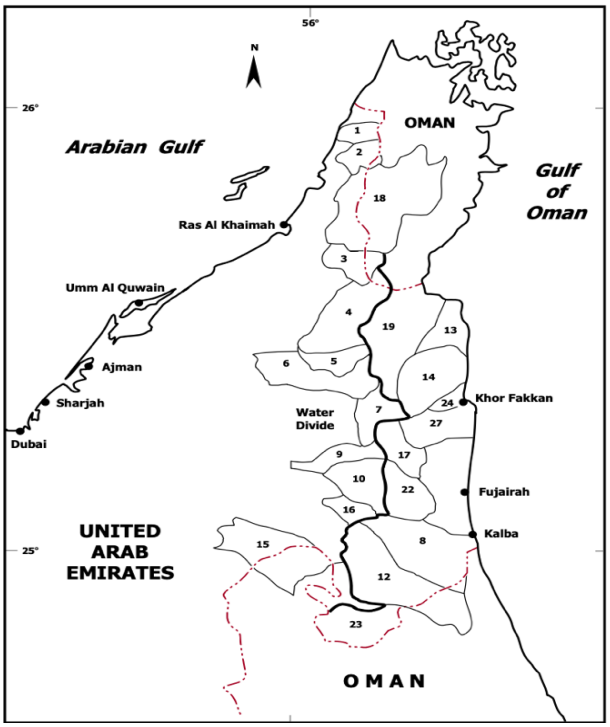

Figure 5: Map of UAE dams and their names (c.f Al-Nuaimi and Murad (2007))

Those 5 classes considered as class of crustacean. While in Kingdom of Saudi Arabia (KSA), studies started long time ago in term of discovering the biodiversity in general and inland water bodies. In their study, Alshammari and Abdelmageed (2011) mentioned that Balfour-Browne (1951) was a pioneer in examining the n-land freshwater organisms such as hemipterans and coleopterans at KSA. While Ataur-Rahim (1979) recorded the presence of Mollusca, Copepoda, Oligochaeta, and Odonata. Another researcher (Siddique, 1979) added Rotifera and Ostracoda to the list. Another study done by Alshammari and Abdelmageed (2011) in Al Ader'a Valley

where samples were taken from 3 areas: Khamashyia lakes (at Prince Sultan Park), El Samrah Pond, and Naqbeen Pond. Resulting in, identifying 25 species (20 rotifers, 3 Cladocera's, and one species of copepods and one of ostracods). The 3 species of Cladocera belongs to the family of Daphniidae and Chydoridae they recorded *Ceriodaphnia cornuta, Alona rectangula* in Khamashyia lakes and *Alona quadrangular* in Naqbeen Pond (Alshammari & Abdelmageed, 2011). Moreover, another study was carried out by Aljohani (2019) in Saudi Arabia, Oman and Jordan, to investigate the springs of the Arabian Peninsula. The study focused on around 76 springs between March and July 2018. The area of study included 15 springs in Saudi Arabia, 41in Oman and 20 in Jordan. It was focusing on investigating water quality and zooplankton, as well as benthos and fish communities in addition to the changes of biota and chemical parameters downstream from the springs source in Saudi Arabia. The study has listed 9 zooplankton taxa, one was a Cladocera, *chydorid Pleuroxus sp*., while the others were rotifers (*Branchionus quadridentatus*, three *Lecane sp.*, and a probable *Trichocerca sp.*). Copepods included one cyclopoid (*Thermocyclops sp.*), and two harpacticoids made up the remaining three taxa (*Euterpina sp, Schizopera sp*). In Saudi Arabia and Oman, two Mollusca (*Pseudosuccinea columella* and *Melanoides tuberculata*) were recorded.

UAE studies of Cladocera is not different than the Arabian Peninsula countries, there is one or two studies with no more investigation or even deep study of Cladocera on the United Arab Emirates. Van Damme and Dumont (2008) studied the morphology and taxonomic rank of several *Alona* species at internal temporal water bodies at UAE. In their study they mentioned an investigation in Africa and the Arabian Peninsula, resulting in recording the first Cladocera species in UAE. The species that was found in UAE was *Coronatella anemae* and the sample was provided by Sharjah Breeding

Centre (Breeding Centre for Endangered Arabian Wildlife (BCEAW)). Van Damme did a deep morphological study describing all the body parts and stages of the *Coronatella anemae* that found in UAE (Van Damme & Dumont, 2008).

The Latest research in UAE done by Hamza et al. (2018), where the first Cladocera organisms in Abu Dhabi Emirate have recorded. The study focused on a dry reservoir sediment behind Al Shuwaib dam near Al-Ain city. The government built the earthen dam to capture rainfall and to protect the village from floods as well as restoring the ground water. Out of sediment sample Hamza et al. (2018) found Cladocera cysts and they were able to hatch it in the laboratory. The outcome of this study was three Cladocera species, that were identified both morphologically and by using molecular analyses as species of *D. similoides*, *D. carinata* and *Alona dentifera* (Figure 6). Hamza et al. (2018) was the first to study the morphology and molecular feature after Van Damme.

The present study is inspired by Hamza's research, to survey the wetlands as well as water bodies within the territory of UAE for living and /or encysted Cladocera species that may change the geographical distribution map of Cladocera around the world.

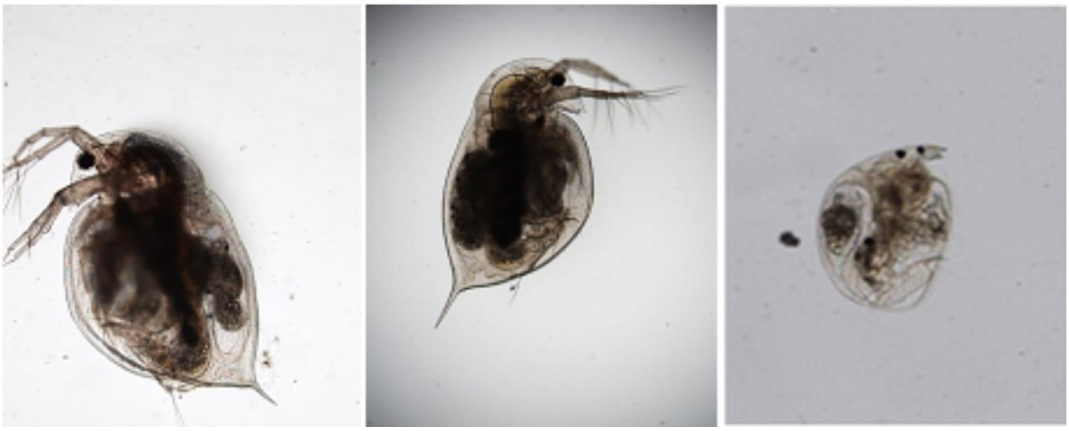

Figure 6: The first identified Cladocera in UAE, (left) *Daphnia similoides*, (middle) *Daphnia carinata*, (right) *Alona dentifera* (c.f. Hamza et al. (2018))

Chapter 3: Methods

3.1 Research Design

The present study conducted with two main aims. The first, was aiming to locating the wetlands in UAE territory, especially the freshwater bodies such as dams, lakes, and wadies (valleys). In addition, to investigate the presence of Cladocera cysts and/or living populations within these wetlands. The second was to identify the Cladocera morphologically by using microscopic identifications based on taxonomic keys and genetically by using molecular techniques.

3.2 Study Locations

Ten sampling sites were chosen based on their accessibility and the Emirates that they are belong to. The selected 10 locations are found to be belonging to the UAE six (6) Emirates as follows: 1- Abu Dhabi Emirate (2 locations, Al Shuwaib Dam, Mubazzarah Historical Dam), 2- Dubai Emirate (2 locations, Hatta Dam, Sheikh Maktoum Bin Rashid Al Maktoum Dam), 3- Ajman Emirate (1 location, Kholaiban Dam Masfut), 4- Fujairah Emirate (3 locations, Wadi Ham Dam, Wadi Fai Dam, Wadi Maidaq - Blue Pool) and 5- Ras Al Khaimah Emirate (2 locations, Wadi Al Qaceesh Dam (Sharjah Dam), Al Ghail Dam) as shown in Figure 7.

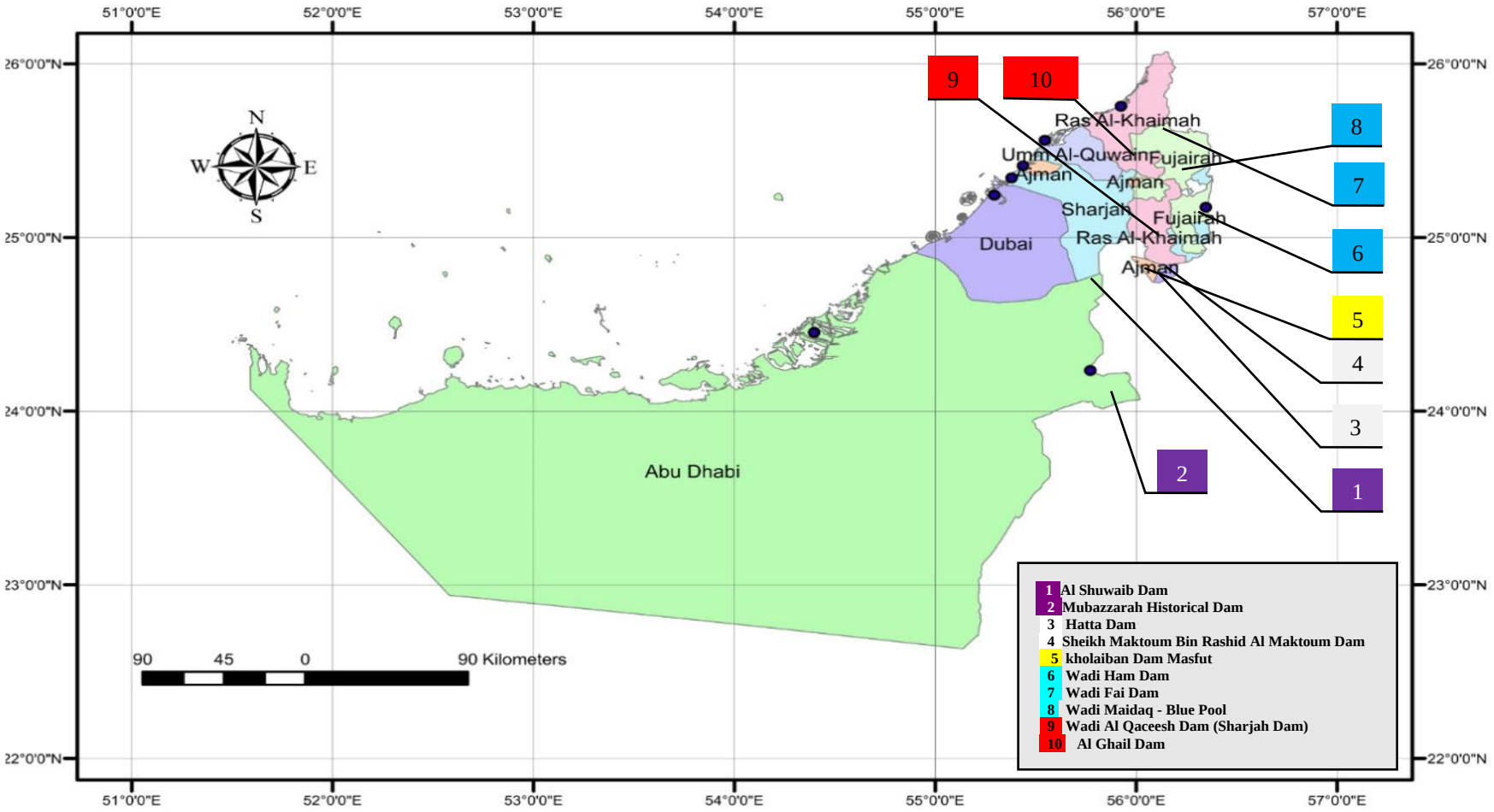

Figure 7: Locations of the sampled 10 dams' basins

3.2.1 Samples Collection

Information about the freshwater wetland in UAE carried out by using google websites, google earth, governmental and personal survey of locally identified sites. At locations where water still there, plankton net samples (mesh size = 80 µm) as well as surface water samples collection in plastic jars have carried out from different places within the same sampling site. However, at locations where no water found but with wet bottom sediments or even dried, sediments samples have collected by hand coring using a Plexiglas tube of 60 cm length and 8 cm diameter. First sample collection was on 1st April 2019 at three deferent dam's wadi Al Ghail (RAK), Wadi Qaceesh Dam (RAK) and Wadi Maidaq - Blue Pool located at Fujairah Emirate (Figure 8).

Figure 8: Examples of sampling locations (upper = Wadi Al Ghail; Lower = Wadi Qaceesh located at Ras Al Khaimah Emirate

All the sampling of other locations were taken with similar method mentioned above for both water and sediment samples. The collected samples brought back to the laboratory at the same day to start investigating of the presence of Cladocera. Net samples collected from water bodies were examined under stereo Microscope. While each core sediment sample was immersed in fresh distilled water from the laboratory at large beakers (2 liters) and 2 ml of chlorella sp. culture dropped on the surface water at the large beaker to allow hatching resting eggs of Cladocera, in case of its presence. All samples (water and sediments) kept at the laboratory at room temperature (21˚C), with 12:12 light/dark conditions.

3.2.2 Resting Eggs Culturing and Hatching

- Two methods of culturing Cladocera were applied.
    - The first method (Onbé, 1978).

This method known as the sugar floating technique (Onbé, 1978). Following Onbé's method, the sugar was prepared in the lab by adding 1000 g of saccharose (glucose) over 1 liter of distilled water to dissolve the glucose completely and have a homogenous solution, the mixture was heated over a heating stove until sugar stock was Prepared. Resting eggs isolation started by taking out the sample from the fridge and leaving the cylinder on the bench till it come to room temperature. The first 10 cm from the top have separated from the rest of sediments and poured into a clean beaker. The total amount mixed using a glass rod, and then divided by weight into two subsamples. The first subsample has sieved through 100 μm net and washed by distilled water into beaker then the content of 20 g of the sieved sample is dispensed in centrifuge tube. Then some of sugar stock has been added to the centrifuge tube containing sediments. Centrifugation was adjusted to 3000 rmp for 5 minutes. The

floated and suspended particles that should contains resting eggs were collected by dropping the upper part of the solution into a clean beaker. The collected materials have washed using distilled water, and then poured into a culturing beaker with fresh water and by adding few drops of *Chlorella vulgaris* culture. cultured in the laboratory. The cultured materials and/or cysts have left for more than a month, but no signs of hatching have recorded.

- The second method.

The second technique as mentioned by Hamza et al. (2018), was by immersing the sediment collected from the upper 10-15 cm with distilled water. Each core sediments, from all the sampled sites were treated with the same technique. They were poured into a 2 liters beaker and immersed with drinking bottled water. The samples were left in the laboratory at room temperature of 21˚C, under 12:12 hours light/dark conditions with a few drops of *Chlorella vulgaris* was added to the surface of the immersed sediment. The sediment was left with weekly monitoring. The hatching date was written down for each sample. After few weeks (3-5 weeks) of immersing under water with few times steering of sediment a microscopic living organism were observed swimming in the supernatant water. These organisms have picked up using Pasteur pipets. The isolated hatched organisms were then transferred into new smaller beakers (250-500 ml), for microscopic identification and morphological taxonomic ranking.

3.3 Cladocera Species Identification

3.3.1 Morphological Taxonomy

Identification of Cladocera's morphologically was the first step after microscopic picked up of living organisms both from net samples and from the

sediment supernatant water. From the original culture using Pasteur pipets and/or plastic dropper few organisms have transferred to a slide to be visualized under stereo microscope (Leica zoom 2000), then under inverted microscope with mounted camera (Olympus CK. X41). Identification of each organism was guided by morphological key book entitled: "Freshwater crustacean zooplankton of Europe: Cladocera & Copepoda (Calanoida, Cyclopoida) key to species identification, with notes on ecology, distribution, methods, and introduction to data analysis (2016)"(Bledzki & Rybak, 2016). As well as Van Damme and Dumont (2008), Van Damme et al. (2011), and Elias-Gutierrez et al. (2019) was also used to identify organisms.

Each species was dissected under the stereo Microscope. Where on a clean slide individual species was dissected using thine micro tungsten needles then covered by a cover slip and examined under the inverted microscope in addition to taking pictures of each species and its body parts. Moreover, a compound Microscope mounted with camera Lucida (Leica Microsystems Leica DM 750) was used to draw the detailed features of each species.

With the allocated fund for research by the College of Science at United Arab University (UAEU), I was able to visit A.N. Severtsov Institute of Ecology and Evolution (Leninsky Prospect 33, Moscow 119071, Russia; Russian Academy of Science- RAS), during the period 21st June 2021 until 4th July 2021 to learn furthermore about morphological identification by dissecting under stereo microscope, light microscope and drawing using camera Lucida. This visit came in the framework of the MOU signed between the Biology Department, UAEU and the A.N. Severtsov Institute of Ecology and Evolution (RAS).

Samples from the original culture found at the biology department laboratory (UAEU) were taken before travel and preserved in small Eppendorf tubes, each tube

contain about 20 individuals of each sample to be morphologically identified. During my journey in Moscow, the camera Lucida drawing was done by the supervision of Prof. Alexey Kotov and Dr. Anna Neritina (RAS). In addition, Scanning Electron Microscope (SEM) was used to obtain some detailed pictures of specific specimens' parts to better identify the collected species.

The sample was preserved in 70% ethanol. Using a needle or pipette, collect the organisms and transfer them to a tiny Petri plate. They cleaned three times with distillate water, each time for five minutes, in a tiny nylon bag. The material is then placed in a nylon bag and immersed in a solution of 1% osmium tetroxide (OsO_4) for 2 hours. After that, the material was cleaned with distilled water before being subjected to an ethanol dehydration sequence utilizing the following concentrations: 25%, 50%, 70%, 80%, 90%, 95, and 100% for 30 minutes each. After that, the material was dried under a high-intensity light overnight (12 hours) over a glass-fiber filter (AP20). Following the specificities of the Scanning Electron Microscope model, the filters must be bonded with commercial glue onto a stub, which is an aluminium foundation. To minimize dehydration, the material on the stub should be moved to a vacuum desiccator and then gold coated before scanning. A 15 kV current intensity and a 15 mm spacing between the sample and the electron beam may be used to analyze the material in the SEM (Felgenhauer, 1987).

3.3.2 Molecular Identification

The second Method in identifying the samples is to use molecular techniques. In this study, the morphologically identified species were cultured until a significant population density developed. At least 20 adult individuals of each species were picked and inoculated into a small Eppendorf tube. Each Eppendorf tube contains absolute

ethanol with 20 individuals from the same species were sent to molecular laboratory of the biology department, UAEU for DNA extraction and sequence analyses as shown in Table 1.

Table 1: List of morphologically identified Cladocera species before its molecular analyses

Label	Sample	Quantity	Collection date	Location	Comment
1	*Moina micrura*	20+	28/10/2019	Masfut Dam	
2	*Ceriodaphnia cornuta*	20 +	28/10/2019	Masfut Dam	
3	*Corntella*	20+	28/10/2019	Masfut Dam	With two pores
4	*Corntella*	20+	28/10/2019	Masfut Dam	With three pores
5	*Anthalona mediterranea*	20+	01/04/2019	Blue pool	
6	*Daphnia*	20+		Alshwaib	
6.1	Long Apical spine	40+	28/1/2021	Alshwaib	Lab culture from executed cysts
6.2	Short Apical spine	40+	28/1/2021	Alshwaib	Lab culture from executed cysts

In the present study two zooplankton-specific primers were used (i.e., LCO1490; HCO2198 as classical primer and ZooplakF1_t1; ZooplankR1_t1 as modified primers by Prosser et al. (2013) to obtain the DNA following the methodology described by Prosser et al. (2013). For the DNA extraction QIAamp DNA Mini Kit (Qiagen, Cat no. 51306) was used following the tissue protocol. Where, DNA extraction and quantification carried on Nanodrop and Qubit Fluorometer (Qubit dsDNA HS Assay Kits, Cat no. Q32851; Thermo Fisher Scientific). The agarose gel electrophoresis was used to check the quality of the DNA extract and its yield. That was followed by PCR amplification with AmpliTaq Gold 360 Master Mix (Cat no. 4398881; Thermo Fisher Scientific). PCR amplicon is purified using ExoSAP-IT PCR Product Cleanup Reagent (Cat no. 78201.1.ML; Thermo Fisher Scientific). Then the Purified amplicons was sequenced with BigDye™

Terminator v3.1 Cycle Sequencing Kit (Cat no. 4337455; Thermo Fisher Scientific). The final step was Sequencing of the PCR amplicon, on 3500 Genetic Analyzer (Thermo Fisher Scientific, Carlsbad, CA, USA). The obtained sequences of the two different primers were compared with the Gene data bank NCBI BLAST of sRNA of the existing sequences.

Chapter 4: Results

The survey done during this study for existing wetland and dams of UAE have revealed the presence of 114 locations that found within the seven Emirates territories (Table 2). Most of the recorded wetlands are found at the North-Eastern regions of UAE (Figure 9). The selected 10 sampling sites were representing both dams and reservoirs basins as well as wetlands either temporary or permanent water bodies (Figure 7) previously mentioned, and (Table 3).

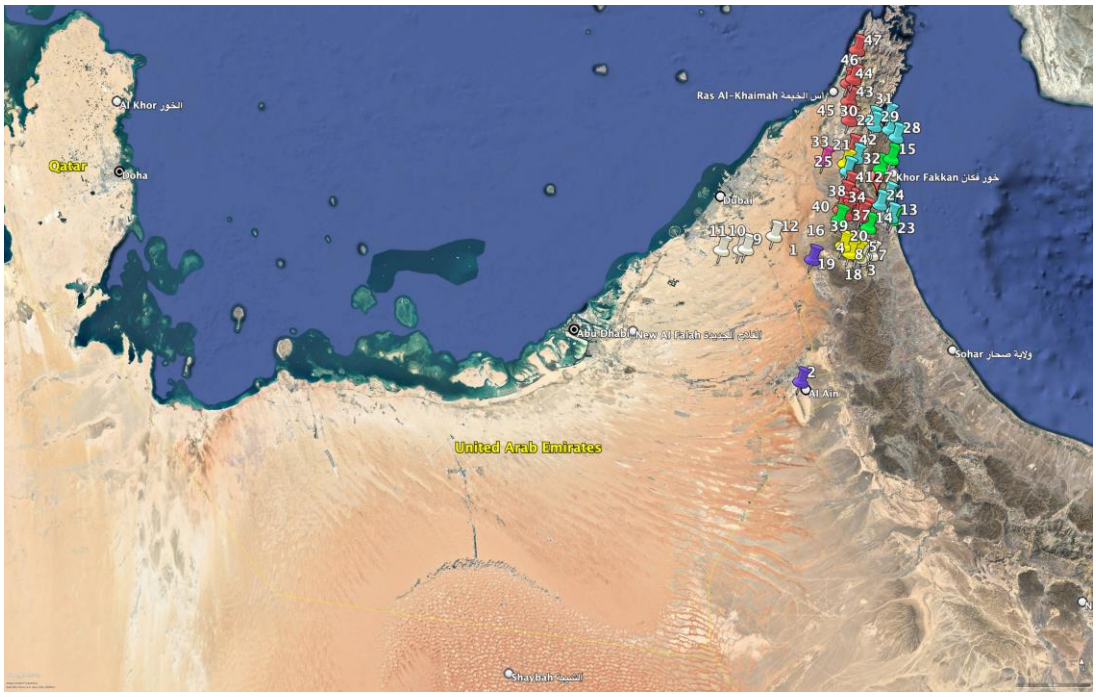

Figure 9: Map of UAE wetlands and dams identified during the present study

Table 2: Wetlands and dams' geographical coordination of the identified locations at the during the present study (sampled locations are shown in red color) in UAE

#	Water Body	Emarits	location
1	**Al Shuwaib Dam**	Al Ain	24.769475520083635, 55.799921842596135
2	**Mubazzarah Historical Dam**	Al Ain	24.097672010385754, 55.74315366957202
3	**Hatta Dam**	Dubai	24.783731667652578, 56.11283323360422
4	Hatta Green Lake	Dubai	24.793927498007147, 56.10659155100111
5	Swan Lake (Hatta - Dubai)	Dubai	24.801593936495035, 56.12263919482573
6	**Sheikh Maktoum Bin Rashid Al Maktoum Dam**	Dubai	24.814009586544948, 56.14275694444807
7	Suhailah Dam	Dubai	24.810721648148505, 56.181012240744735
8	Leem Lake	Dubai	24.81516876694388, 56.12976297082087
9	Heart Lake Dubai	Dubai	24.838528184149983, 55.405062583073274
10	AlQudra Flamingo Lakes	Dubai	24.84510711905078, 55.35145118036275
11	Al Qudra Lake (not the original)	Dubai	24.831575490722287, 55.254242045983965
12	Dubai Lake	Dubai	24.912833912315964, 55.57849068750886
13	Kalba Dam	Sharjah	25.010438787069145, 56.318584973074636
14	Wadi al Rabka Dam	Sharjah	24.96220406322603, 56.16415602910621
15	Al Rafisah Dam	Sharjah	25.348977333846058, 56.31123719842369
16	Buraq Dam	Sharjah	25.005725024437563, 55.98270785423963
17	Wadi Shees	Sharjah	25.291150032084847, 56.24461328452931
18	**Kholaiban Dam Masfut**	Ajman	24.81018967706477, 56.092777286710486
19	Muzaireh Dam	Ajman	24.818153125284702, 56.04783435472828
20	Wadi Jazeer Dam	Ajman	24.861780717230417, 56.00639906349577
21	Bayya Dam	Ajman	25.3197524510616, 56.02336905609516
22	Wadi Zikt Dam	Fujerah	25.511119792474624, 56.299242466197136
23	Ramath Dam	Fujerah	25.02024330259061, 56.30467881376319
24	Wadi Al Hayl Dam	Fujerah	25.090323632184653, 56.23516205424059
25	Siji dam	Fujerah	25.27688589670137, 56.03244568307889
26	Fujairah Dam	Fujerah	25.13468270334741, 56.29530946263774
27	**Wadi Ham Dam**	Fujerah	25.138753848028593, 56.28406148492888
28	Sharm Dam	Fujerah	25.46887010440336, 56.34168792726114
29	Al Basera Dam	Fujerah	25.53138362002953, 56.204639469589914
30	**Wadi Fai Dam**	Fujerah	25.562229035908896, 56.19248945609838
31	Dalam Dam	Fujerah	25.582946469710226, 56.28924606959066
32	**Wadi Maidaq - Blue Pool**	Fujerah	25.352047573435847, 56.08863733952748
33	Falaj Al Mualla Dam	Umm Alq	25.339085369590627, 55.88997920843564
34	Wadi Tuwa Dam	RAK	25.022167185195393, 56.12627035833578
35	HILUW 2 Dam	RAK	25.047023382178917, 56.139853896568326
36	Shawkah Dam	RAK	25.105753574398523, 56.04269335782136
37	Wadi Modaynah Dam	RAK	25.033933856262138, 56.02092221376335
38	Al Mansab Dam	RAK	23.54905060264438, 58.34327021212563
39	Al Layat Dam	RAK	25.082314557702052, 56.00558637143574
40	**Wadi Al Qaceesh Dam (Sharjah Dam)**	RAK	25.139891134637246, 56.01394006958489
41	Esfani dam	RAK	25.190208154483656, 56.042031198421654
42	**Al Ghail Dam**	RAK	25.399758268455667, 56.06679205609597
43	Nahela Dam	RAK	25.67015908242234, 56.0474506137715
44	Wadi Qida'a Dam	RAK	25.773214053304685, 56.04367844075727
45	Wadi Taween Dam	RAK	25.56440093222244, 56.048703256098406
46	Wadi Beeh Dam	RAK	25.797864460016267, 56.076714111921575
47	Wadi Ghalilah Dam	RAK	25.98489578429431, 56.14541777144134
48	Wadi Shawka - Pool	RAK	25.094748409645074, 56.065999940748526

Table 3: Geographical coordinates of the sampled Ten (10) wetlands and dams

#	Dam	Emarits	location
1	Al Shuwaib Dam	Al Ain	24.769475520083635, 55.799921842596135
2	Mubazzarah Historical Dam	Al Ain	24.097672010385754, 55.74315366957202
3	Hatta Dam	Dubai	24.783731667652578, 56.11283323360422
4	Sheikh Maktoum Bin Rashid Al Maktoum Dam	Dubai	24.814009586544948, 56.14275694444807
5	Kholaiban Dam Masfut	Ajman	24.81018967706477, 56.092777286710486
6	Wadi Ham Dam	Fujerah	25.138753848028593, 56.28406148492888
7	Wadi Fai Dam	Fujerah	25.562229035908896, 56.19248945609838
8	Wadi Maidaq - Blue Pool	Fujerah	25.352047573435847, 56.08863733952748
9	Wadi Al Qaceesh Dam (Sharjah Dam)	RAK	25.139891134637246, 56.01394006958489
10	Al Ghail Dam	RAK	25.399758268455667, 56.06679205609597

Out of the sampled ten dams' basins, four samples cultured in the lab have shown the presence and execution of Cladocera species. Cyst execution technique described by Hamza et al. (2018) was used to establish cultures of the identified species listed in Table 4.

Table 4: Cladocera species identified from the investigated dams water and sediments of its basins

# No	Species	Location(dam)	Emarites	Coordinates
1	*Moina micrura*	Masfut Dam	Ajman	24.810, 56.092
2	*Ceriodaphnia cornuta*	Masfut Dam	Ajman	24.8101, 56.092
3	*Coronatella anemae*	Masfut Dam, Wadi Ham Dam, Wadi Maidaq blue pool	Ajman Fujerah Fujerah	24.810, 56.092 25.138, 56.284 25.352, 56.0886
4	*Anthalona mediterranea* "Based on Morphological comparison"	Masfut Dam, Wadi Ham Dam, Wadi Maidaq blue pool	Ajman Fujerah Fujerah	24.810, 56.092 25.138, 56.284 25.352, 56.088
5	*Dhapnia similoidis*	Al Shuwaib Dam	Al Ain	24.7694, 55.799

Most of the retrieved Cladocera species have detected in the water of Masfut Dam and its sediments. The first species to be visualized was *Moina Micrura*, then *Ceriodaphnia Cornuta*. *Coronatella anemae* and *Anthalona mediterranea* were difficult to detect in the water sample but it was easy to find within sediments under the light microscope. However, taxonomic comparisons between *C. Anemae* and

A. mediterranea were very difficult because of the great similarity of their body shape and size, however, with the use of inverted Microscope and SEM distinguishable differences were detected by the differences in their labarum setae; as shown below. For each identified species pictures of light inverted Microscope, Scanning Electron Microscope (SEM) and Camera Lucida hand drawing have documented in this study to show the detailed differences that have been used to give the taxonomic nomenclature for each species collected during the present study. That is in addition to its confirmation by molecular analyses and its sequence comparison with the gene bank data (NCBI-BLAST) as follows:

4.1 Moina Micrura

4.1.1 Light Microscope Identification

Moina micrura was visualized under microscope and dissected to show the different body part to determine the species identity. The body of *M. micrura* is so delicate unlike other species. Most picture was taken while the animal is still alive unless it is dissected. Deferential diagnosis of *M. micrura*, 2nd antenna (Figure 11 H-J) in parthenogic and ephippial females is identical (Figure 12 O and Q-R, and Figure 15 A-B). The coxal portion has two setulated sensory setae, one of which is long and reaches the length of the basal segment, and the other is small and thin. The basal segment is strong, with a distal spine on the dorsal face that is as long as the first segment of a 4-segmented antennal branch. A comparable armature may be seen on the lateral seta on the third segment of the dorsal branch. The ventral branch's basal and distal lateral setae are armed differently: the basal segments are uniformly setulated, while the distal segments are asymmetrically setulated. Like apical spines, the spine on the first endopodite segment is short. Three long, apical swimming setae

on both antennal branches, all with delicate, lengthy setules on the basal and distal segments. A comparable armature may be seen on the lateral seta on the third segment of the dorsal branch. The ventral branch's basal and distal lateral setae are armed differently: the basal segments are uniformly setulated, while the distal segments are asymmetrically setulated. Like apical spines, the spine on the first endopodite segment is short (Elias-Gutierrez et al., 2019).

The 1st antenna is rod-shaped, roughly four times longer than broad, almost cylindrical, with transverse rows of dispersed denticles on the anterior face and a row of long setules on the posterior face (Figure 10 E-G, Figure 14 B-D, and Figure 15 C). Antennular sensory seta conical, elongated, middle lateral face. Small thick spinules on distal tip. 9 aesthetascs, 2 somewhat longer. Each aesthetasc has a crown-like projection on the tip. Post abdominal claw with curled tip. Surrounding the dorsal border is a series of lesser spines creating a row from mid-claw to bare tip, with the basal pecten consisting of 4 to 8 thin spines packed together. Some had basal and middle pectens joined. Inner face of claw has a row of spinules. 4-7 big denticles around claw base (Figure 11 K-N, Figure 14 E, and Figure 15 D-E) (Elias-Gutierrez et al., 2019).

Male (Figures 13 and 16), head (Figures 13 B and 16 B) longer than female, no rostrum, less fleshy labrum. Antennule tall (Figure 13 C-E and Figure 16 C), male seta and sensillum inserted in first third of antennule. Distally, nine aesthetascs and three to four hooks of varying size and orientation are present. Antenna – armature like female. Spirules on distal border of all segments. A broad copulatory hook, two spinules on endite 4 Inner Distal Lob (IDL), and one seta on endite 3 (Figure 16 F-G). Ventral face has a row of robust bristles. Wart-like growth near hook's inner base. Post abdomen (Figure 13 F-G and Figure 16 D-E), like female, but shorter, with 4-5

setulated teeth, the distalmost narrow and pointed. Female distal bident tooth 10 teeth in middle pecten (arranged fan-like) and 5-7 on ventral side at basal half of claw. lateral gonopores (Figure 16 E) (Elias-Gutierrez et al., 2019).

Moina Micrura visualized under the Scanning Electron Microscope-SEM, pictured different body part of *M. micrura* (Figure 14).

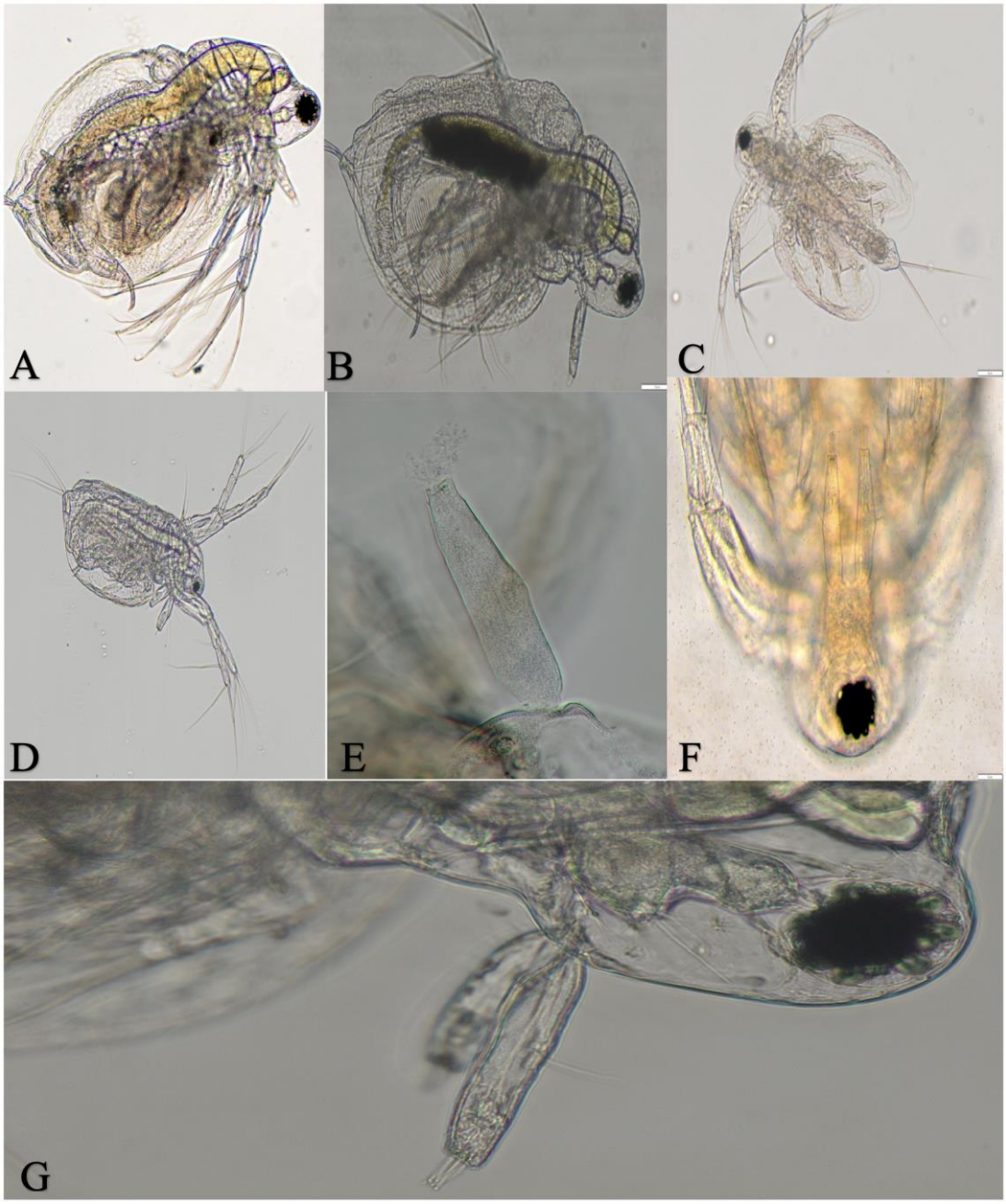

Figure 10: *Moina Micrura* picture under light microscope. (A- B) adult female, (C) juvenile female, (D) ventral side of juvenile female body, (E-G) adult female 1st antenna and antennule

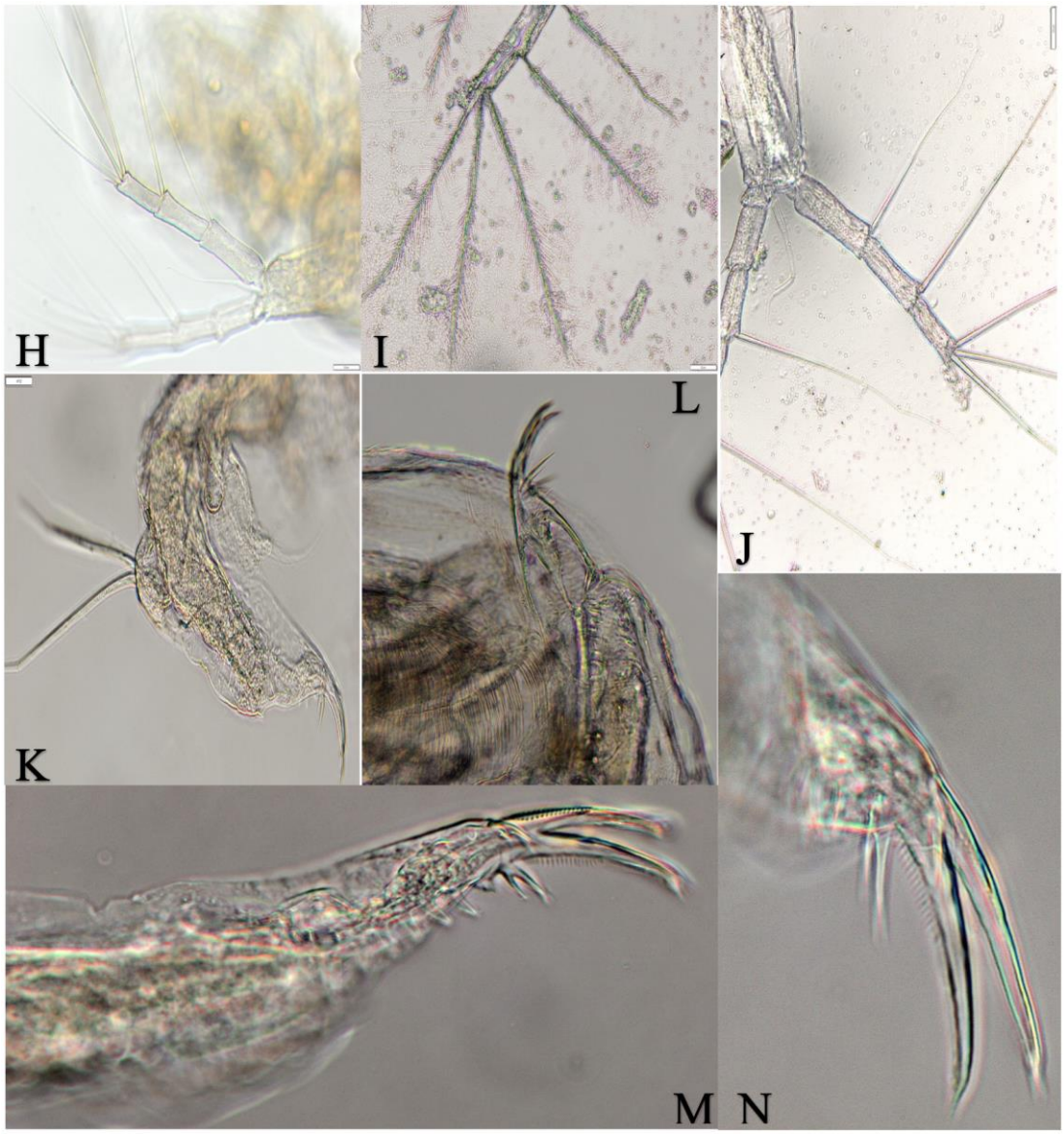

Figure 11: *Moina Micrura* female. (H-J) 2nd antenna with apical dorsal spine and ventral seta of the basipodite, (K-N) postabdominal, claw and dorsal seta

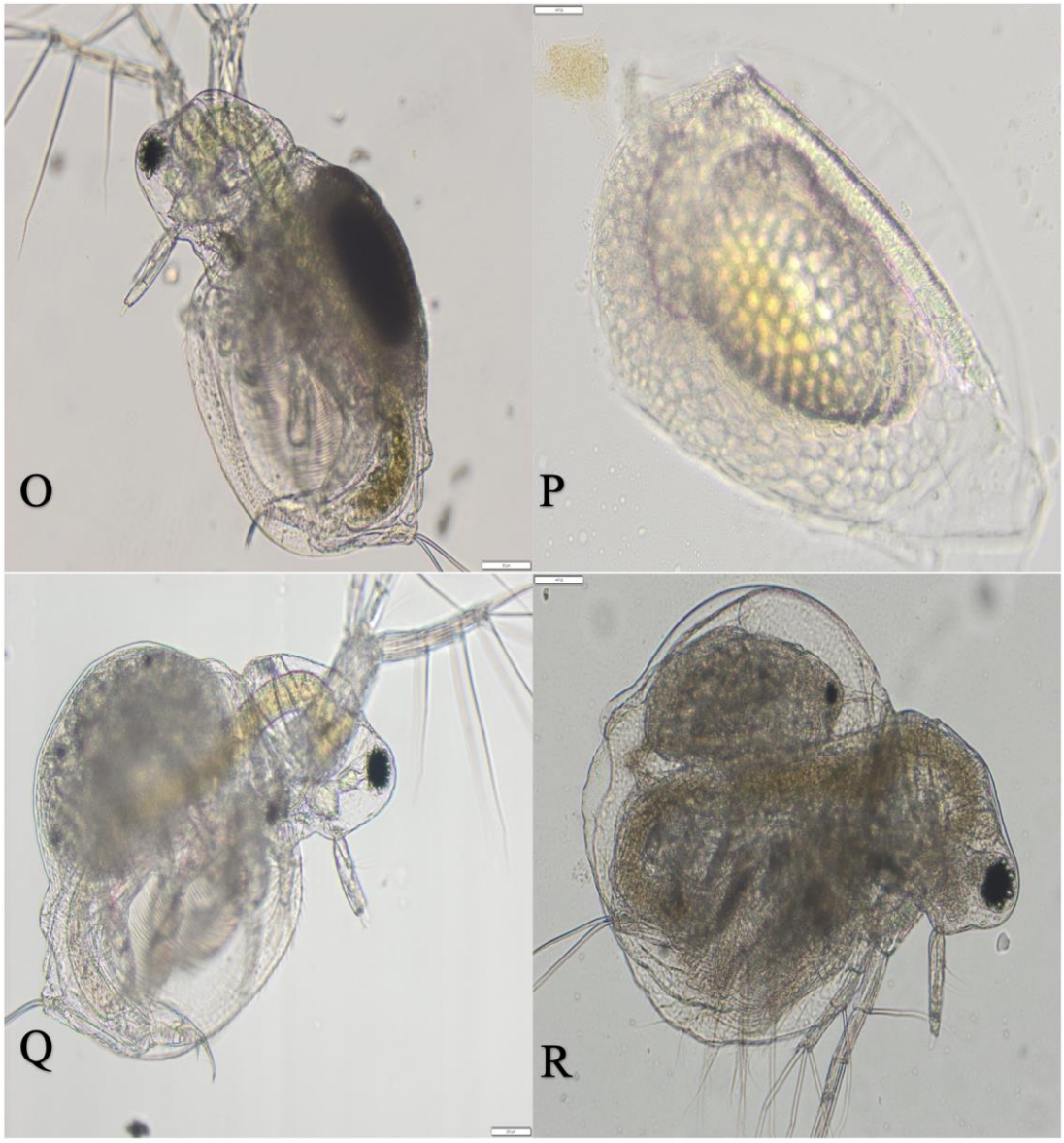

Figure 12: Female *Moina Micrura* in sexual stage. (O) female carry the egg in the carpus, (P) ephippium the sexual stage result is egg that will be released in the environment, (Q-R) female *M.micrura* in parthenogenetic stage (default mode)

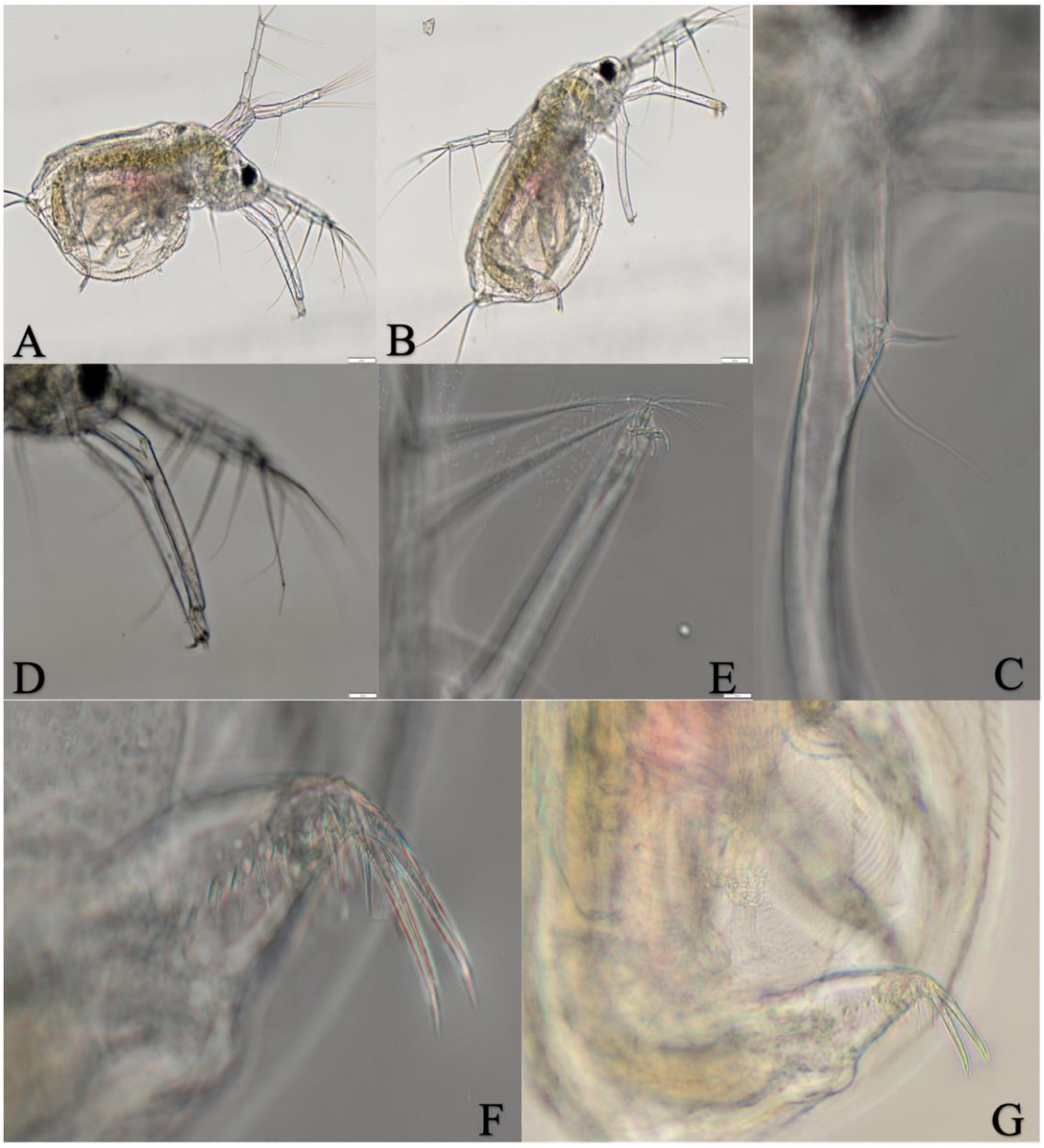

Figure 13: Male *Moina Micrura*. (A-B) ventral side full body, (C-E) 1st antenna of male, (C) setules in the 1st antenna of *M. micrura* male, (E) tips of antennules, (F-G) post abdomen claws

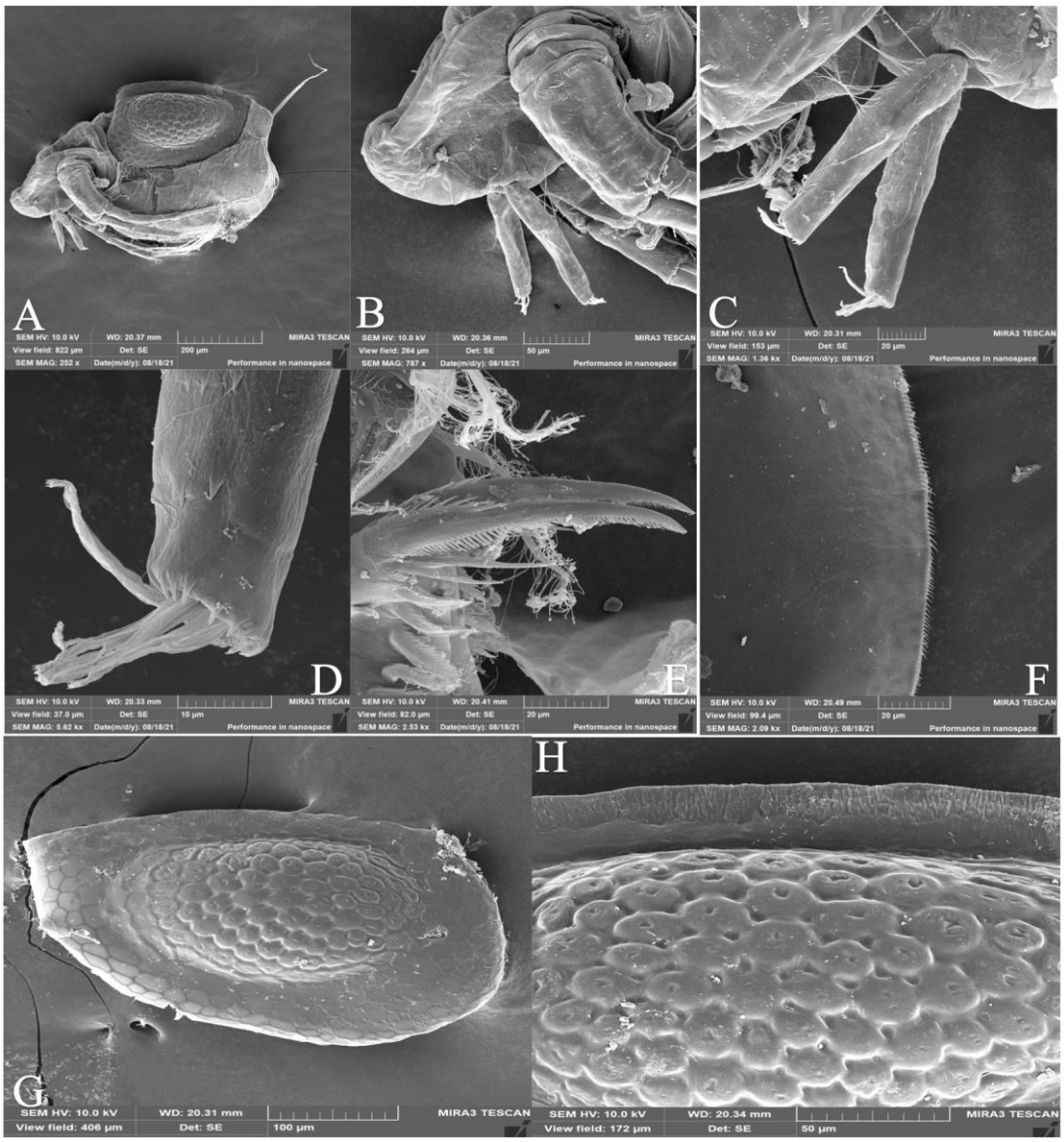

Figure 14: *Moina Micrura* under SEM. (A) full body of female in sexual stage carrying Ephippium, (B) female head with 1st antenna and 2nd antenna, (C-D) clear picture of 1st antenna with the satules, (E) postabdomenal claws, (F) satules on the outer part (valves), (G-H) ephippium, resting egg outer shell pattern

4.1.2 Camera Lucida- Hand Drawing

Using camera lucida *M. micrura*, individual and body parts were drawn and grouped using computer software to obtain these final drawings.

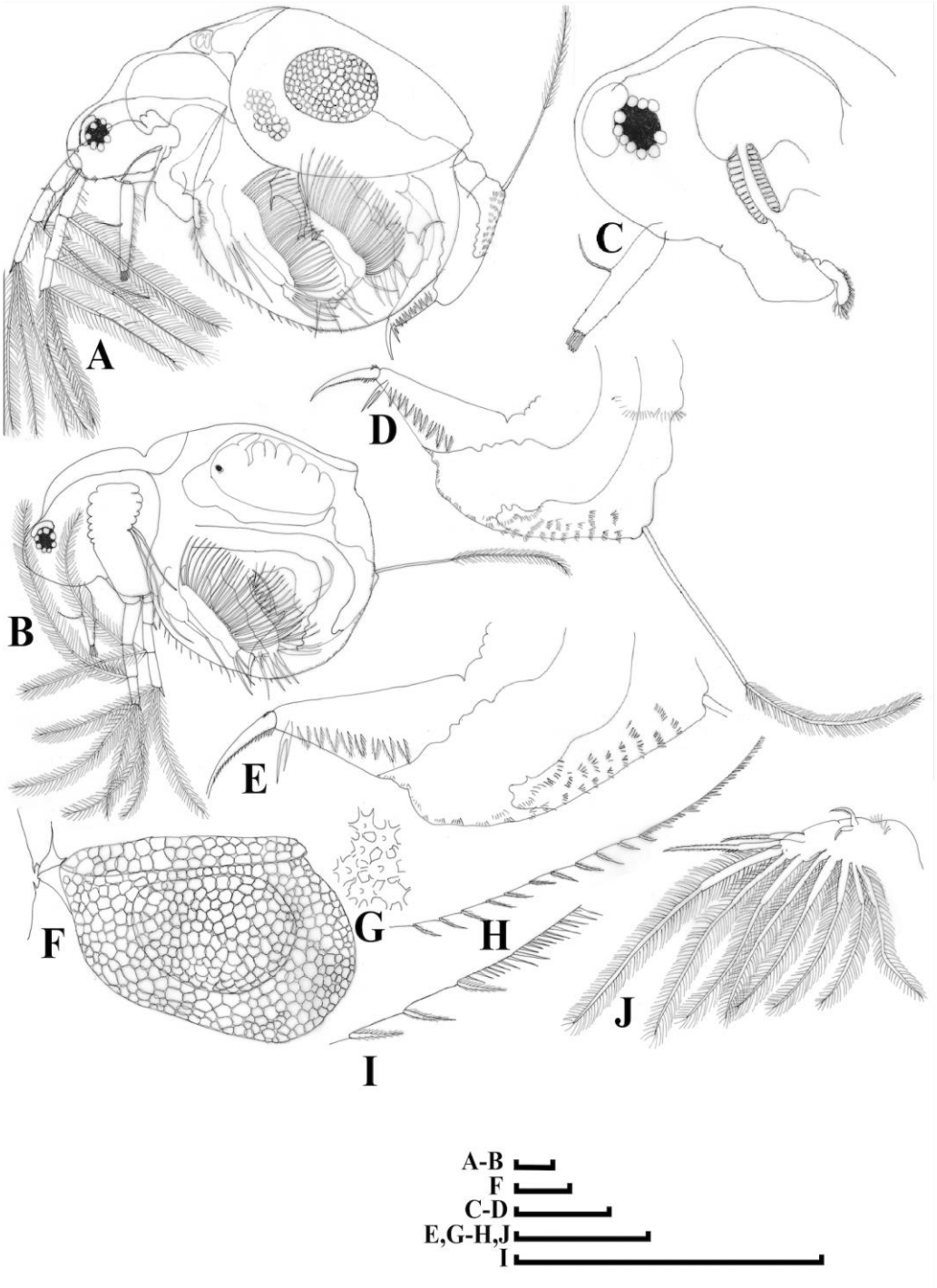

Figure 15: *Moina Micrura* pictures using camera lucida. (A) external structure of *M. micrura* in sexual stage carrying Ephippium, (B) full body parthenogenesis stage, (C) head and 1st antenna, (D) full post abdomen, (E) post abdomen claws, (F) ephippium, (G) patterns on the Ephippium (egg), (H,I) valves spines, (J)1st limb. Scale bar denotes 0.028 µm (A, B), 0.054 µm (C, D, F), and 0.141 µm (E, G -J)

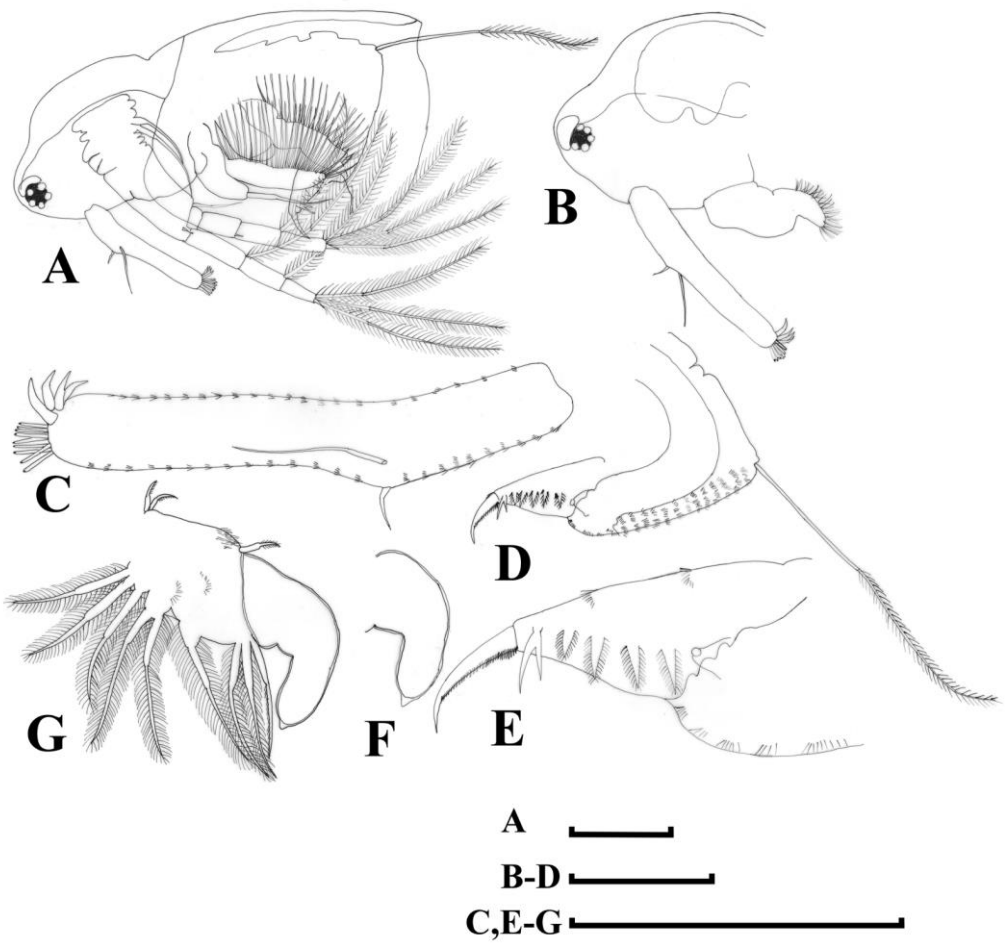

Figure 16: Male *Moina Micrura* pictures using camera lucida. (A) adult male *M. micrura*, (B) head lateral view with long 1st anntena, (C) male 1st antenna with antinual, (D) lateral view of full postabdomen, (E) lateral view of postabdomen claws and spine, (F-G) male portion of 1st limb. Scale bar denotes 0.015 µm (A), 0.054 µm (B, D), and 0.141 µm (C, E-G)

4.1.3 Molecular Analyses

The phylogenetic tree resulted from the COI sequence of *M. micrura* is confirming its morphological taxonomic ranking as shown in Figure 17. The comparison of *M. micrura* sequence with the gene bank, showed a difference of 13 leaves, but it has 98% matching with the archived gene sequences of the same species.

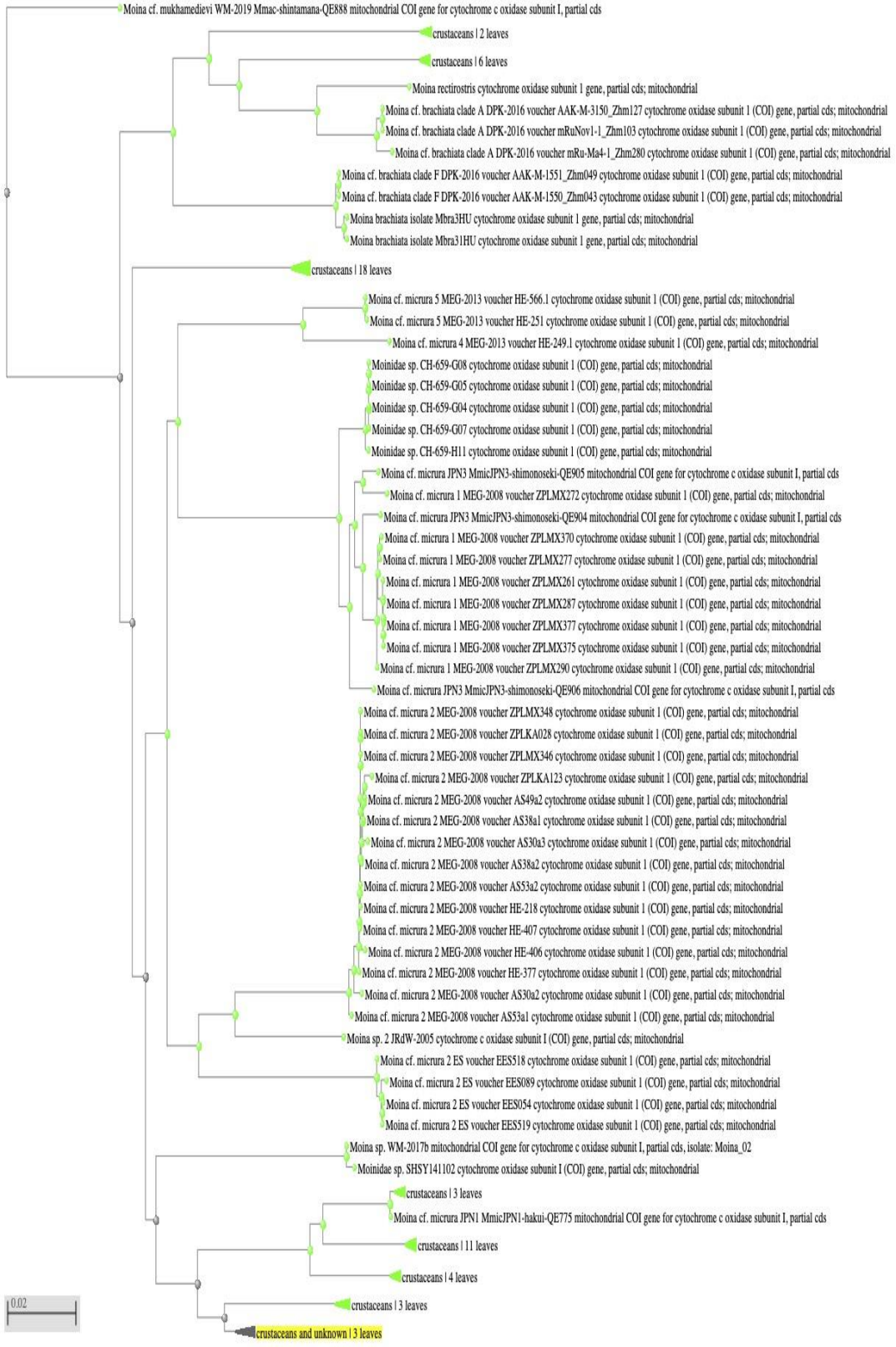

Figure 17: Phylogenetic tree resulted from the COI sequence *Moina Micrura*

4.2 Ceriodaphnia Cornuta

Ceriodaphnia cornuta is the most abundant in the culture easily to find all the time. Unlike *M. micrura, Ceriodaphnia cornuta* is much easier to handle and dissect under microscope. Deferential diagnosis *C. cornuta* checking the five limbs, general shape ,1st antenna, 2nd antenna and post abdomen (Figures 18-21). External structure and body part of *C. cornuta* pictures captured by SEM (Figure 19).

4.2.1 Light Microscope Identification

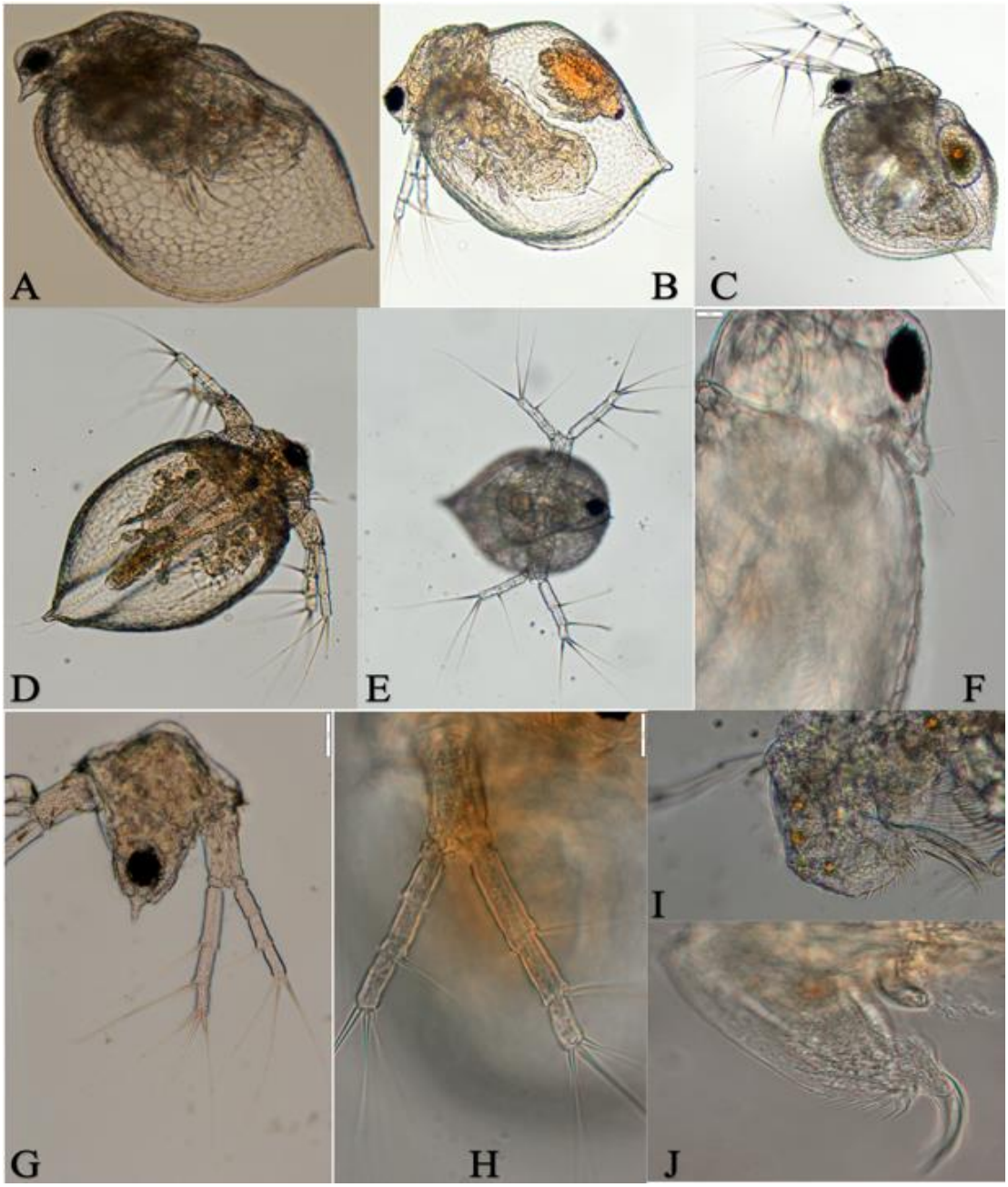

Figure 18: Female *Ceriodaphnia cornuta* under light microscope pictures. (A) external structure of female *Ceriodaphnia cornuta* ventral side, (B) female ventral side in parthenogenetic stage, (C) female in sexual stage carrying ephippium, (D) female posterior side, (E) interior side of female, (F) ventral side of female head with 1st antenna, (G) interior side of the head and 2nd antenna, (H) 2nd antenna with basipod, endopodite and exopodite, (I-J) postabdomen ventral side with the claws

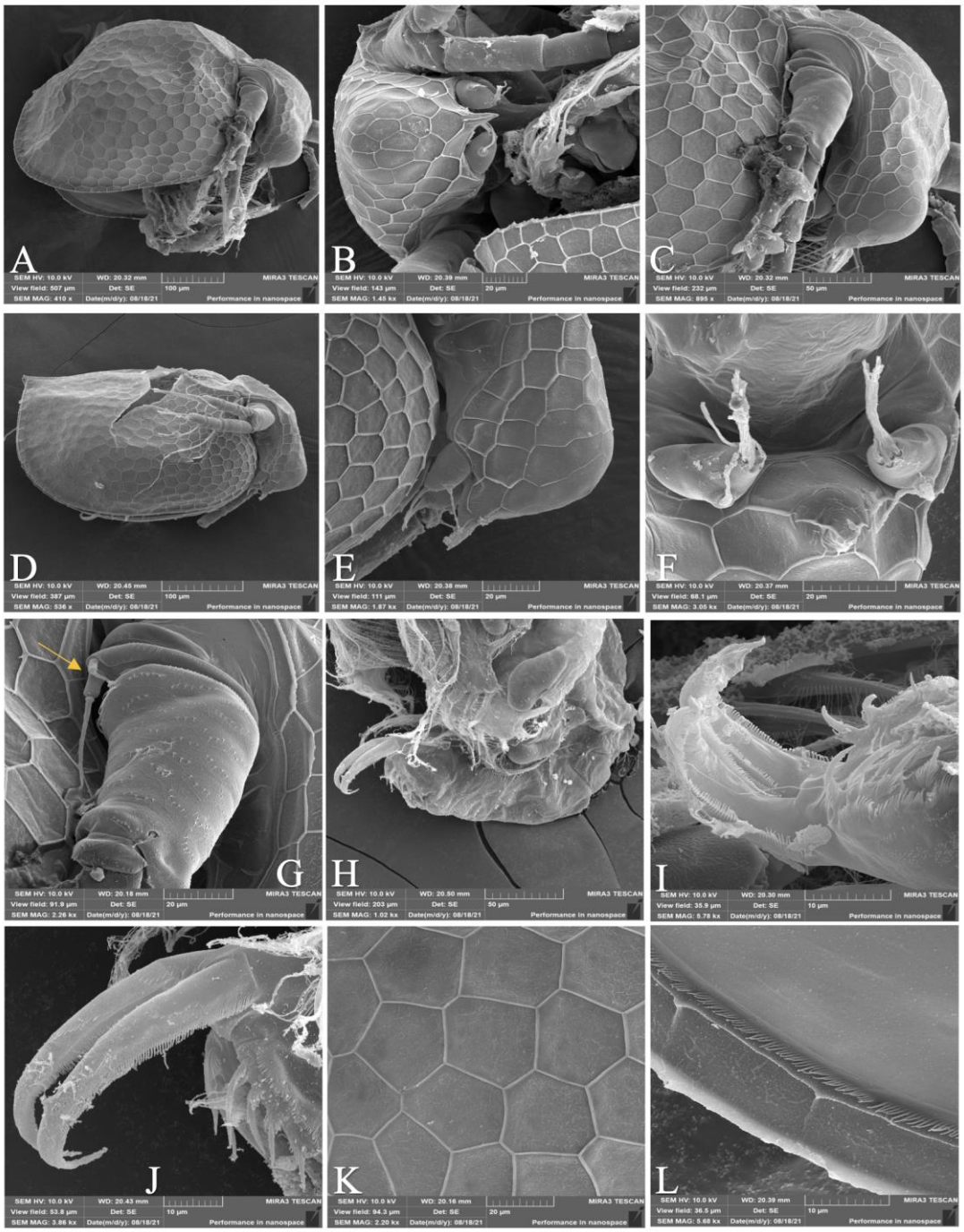

Figure 19: External structure and body part of *Ceriodaphnia Cornuta* pictures captured by SEM. (A) ventral side of *C. cornuta*, (B) female head with 1st antenna and 2nd antenna, (C) 2nd antenna basipod and carpus patterns, (D)another female outer body structure ventral side, (E) head shape and the 1st antenna, (F) antenula of the 1st antenna, (G) Basipod of 2nd antenna, (H) postabdomen, (I) post abdominal claws dorsal side, (J) post abdominal claws, (K) valves exterior patterns, (L) armature of ventral margin of valve

4.2.2 Camera Lucida – Hand Drawing

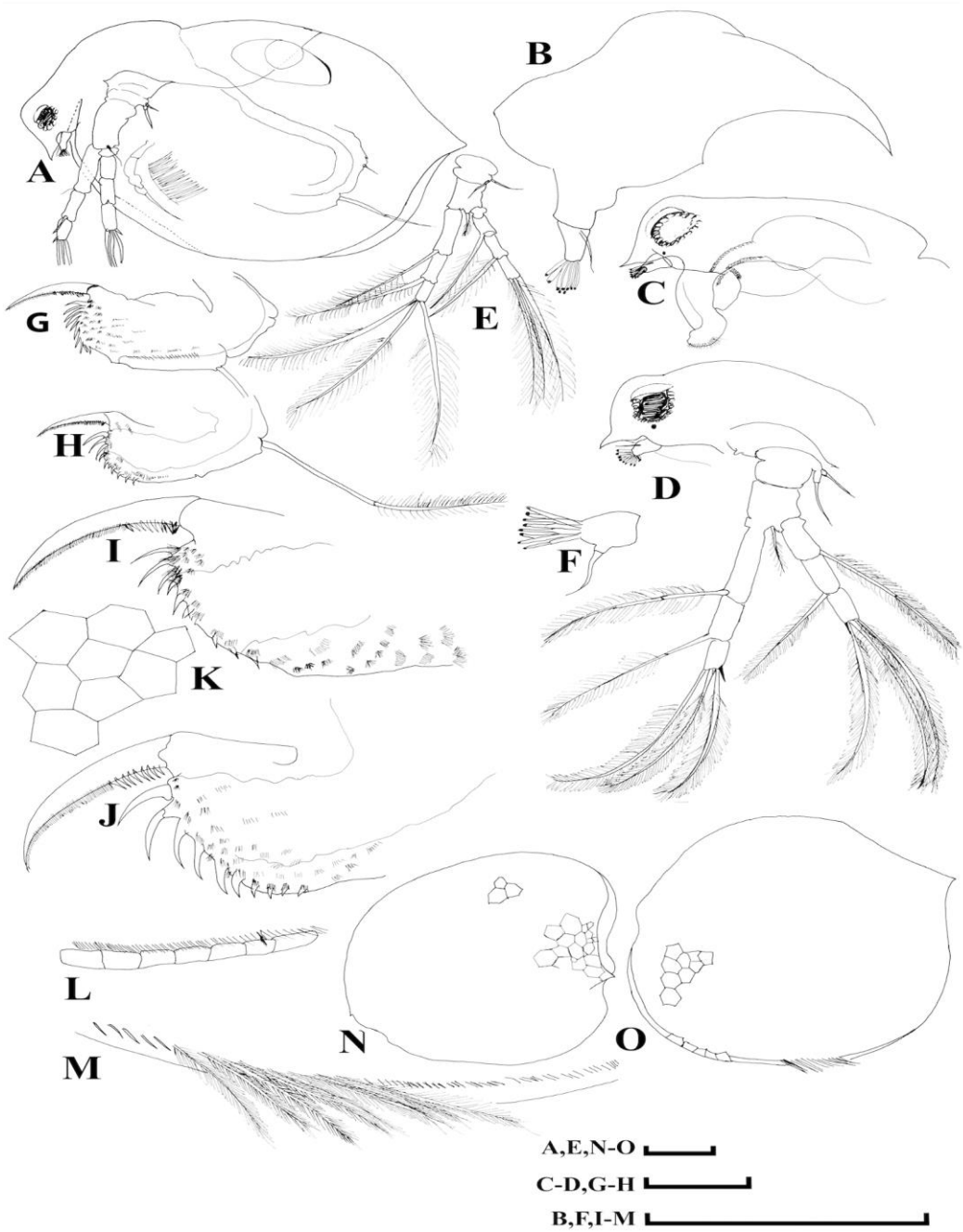

Figure 20: *Ceriodaphnia cornuta* parthenogenetic female pictures using camera lucida. (A) adult parthenogenetic female full body structure ventral side, (B) head portion with 1st antenna, (C) head and rostrum, (D) head rostrum and 2nd antenna ventral side, (E) 2nd antenna with basipod, endopodite and exopodite, (F) 1st antenna with antennule, (G-J) postabdomenal and post abdominal claws, (K) valves patterns reticulation, (L-O) valves reticulations and ventral side of the valve. Scale bar denotes 0.028 µm (A, E, N-O), 0.054 µm (C-D, G-H), and 0.141 µm (B, F, I-M)

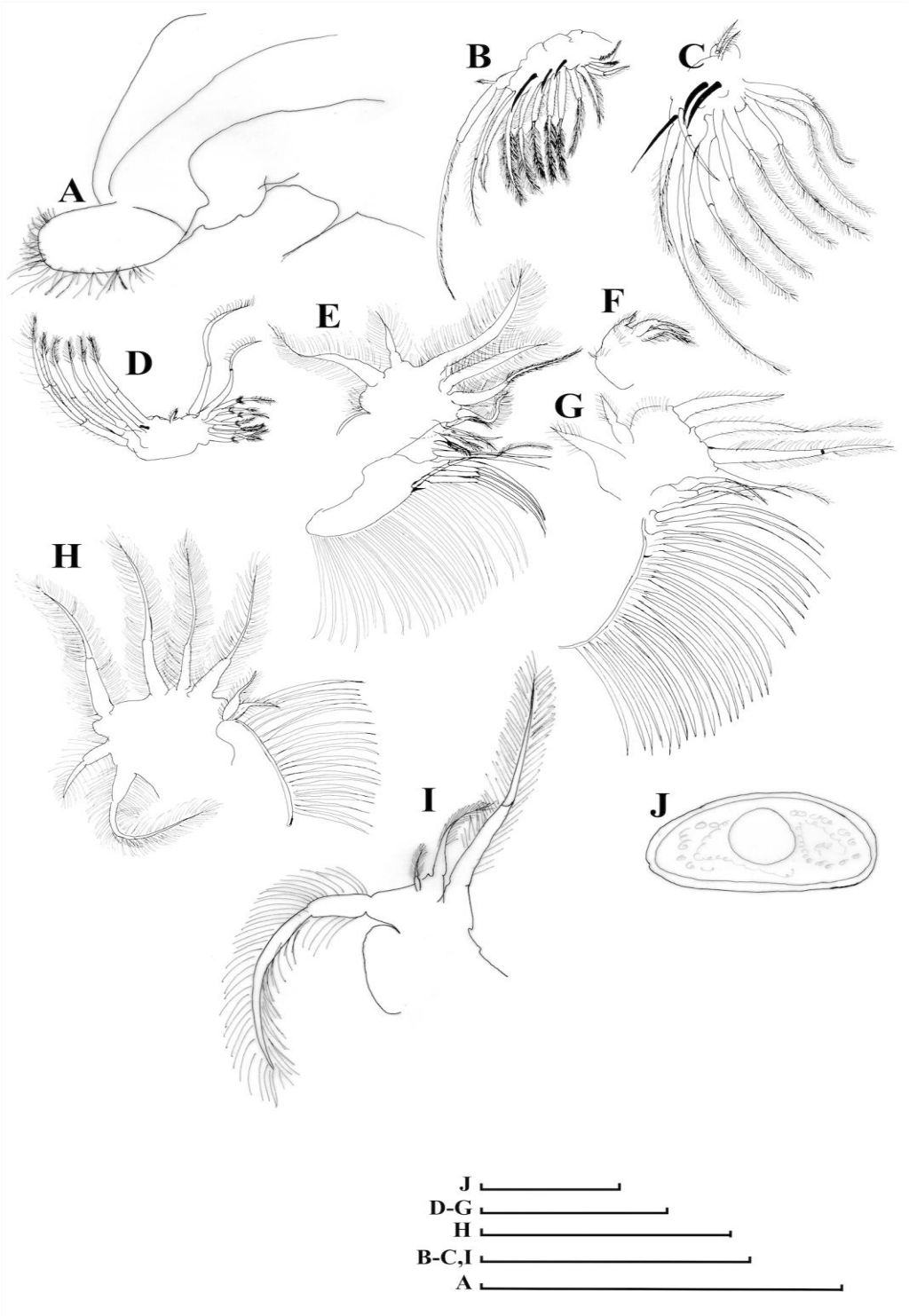

Figure 21: Thoracic limb of female *Ceriodaphnia cornuta*. (A) labrum, (B-C) Limb I, (D) limb II, (E-G) limb III, (F) Outer Distal Lob (ODL), (H) limb IV, (I) limb V, (J) ephippium. Scale bar denotes 0.054 µm (J), and 0.141 µm (A-I)

4.2.3 Molecular Analyses

The phylogenetic tree resulted from the COI sequence of *C. cornuta* is confirming its morphological taxonomic ranking as shown in Figure 22.

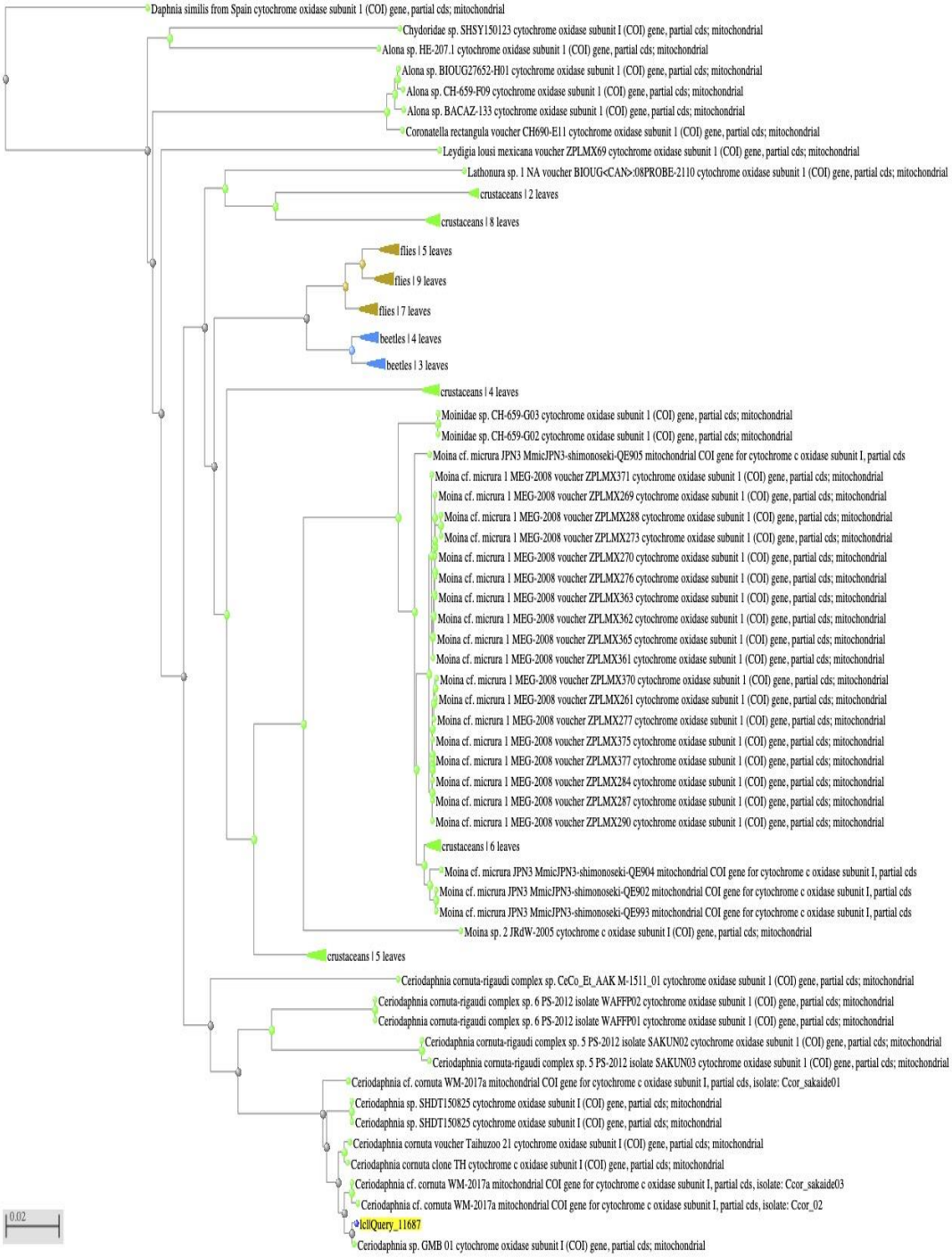

Figure 22: Phylogenetic tree resulted from the COI sequence of *Ceriodaphnia cornuta*

4.3 Coronatella Anemae

4.3.1 Light Microscope Identification

Coronatella anemae, very small in size (0.4–0.55 mm) barely can be detected in the water by naked eye. Under stereo microscope and light inverted microscope dissection was done to obtain picture of the species. To differentiate *C. anemae* we need to check the 2nd antennae, 1St limb, post abdomen, general look of the species as well as head pores based on (Van Damme & Dumont, 2008). For the 2nd antennae, (Figure 24 B-C and E, and Figure 26 B and F) large, conical coxal spine. Long and thin first exopod seta on antenna, extending beyond final antennal segments; group of six to eight long spinules on exterior side of second exopod segment, the first endopod segment's spine is as long as the second endopod segment's; the endo- and exopod's major terminal spines are well-developed and as long as the final segment. Terminal setae are subequal in length and do not extend beyond the animal's dorsum. 1St limb (Figure 26 G) epipodite that is oval and has no protrusion. The first endite has three marginal setae, the first of which is well developed, the second has three setae, two of which are longer (and subequal in size), and the third has four setae; anterior components on en1–2 are present but minute, one on each endite. ODL with one slender seta about as long as longest IDL seta; IDL with two setae, third seta is reduced. Three or more robust setules in each anterior setule group, progressively diminishing in size ventrally. Slender, subequal gnatho base with long single setulated seta ejector hooks. While the post abdomen (Figure 23 C, Figure 24 H-L, Figure 25 M, and Figure 26 C-D) similar length preanal, anal, and postanal margins (post-anal portion may be slightly longer than anal margin). The ventral margin is the same length as the anal and postanal margins combined. The ventral margin is the same length as the anal

and postanal margins combined. The ventral margin is the same length as the anal and postanal margins combined. Anal edge is totally straight, with a little concavity right before the preanal corner, but most of the time terminating abruptly. Strongly developed preanal corner, triangular, projecting beyond anal and postanal boundaries. Denticles on the margins are highly developed and organized into eight to ten postanal clusters. Distal postanal marginal denticles with two or more big spines, in clusters of three to four long spines closest to the anal edge, with the distal element greatest. Five to seven lateral fascicles in the postanal section, each with about 15 thin spinules, parallel to one another, of similar thickness and slightly increasing in size distally. In the anal region, there are two to three clusters of marginal denticles and a double row of fascicles. There are three main head pores of the same size, narrowly connected (Figure 23 D, Figure 25 Q, and Figure 26 A-B) (Van Damme & Dumont, 2008).

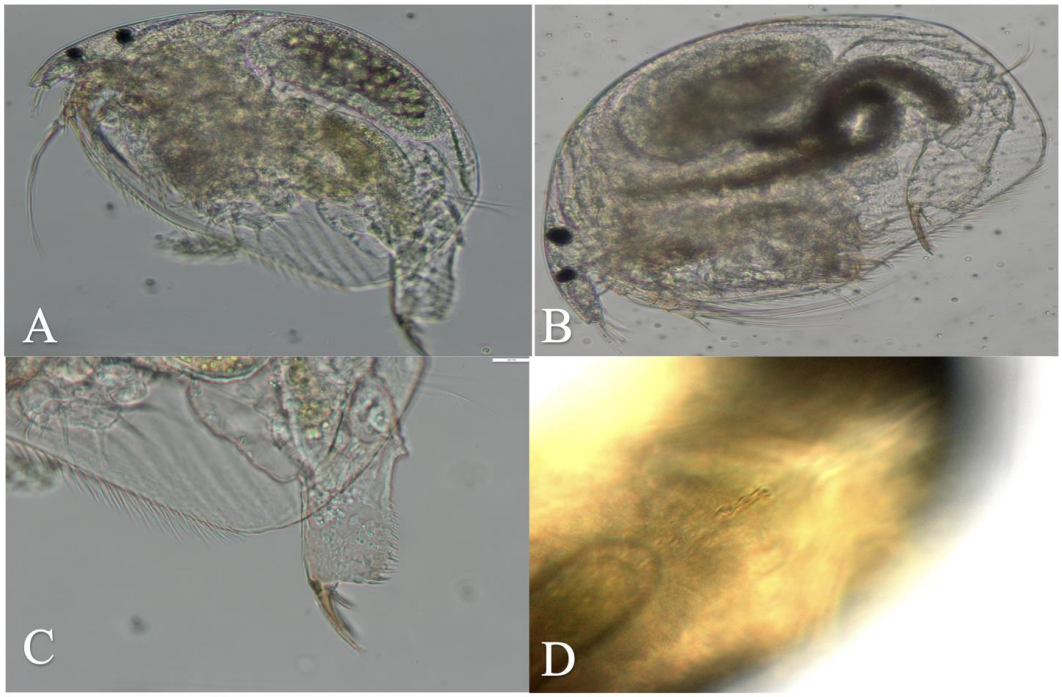

Figure 23: *Coronatella anemae* female pictures under light microscope. (A-B) female ventral side in parthenogenetic stage, (C) postabdomen, valve and the armature of ventral portion of the valve, (D) head sheld with the dorsal three pores

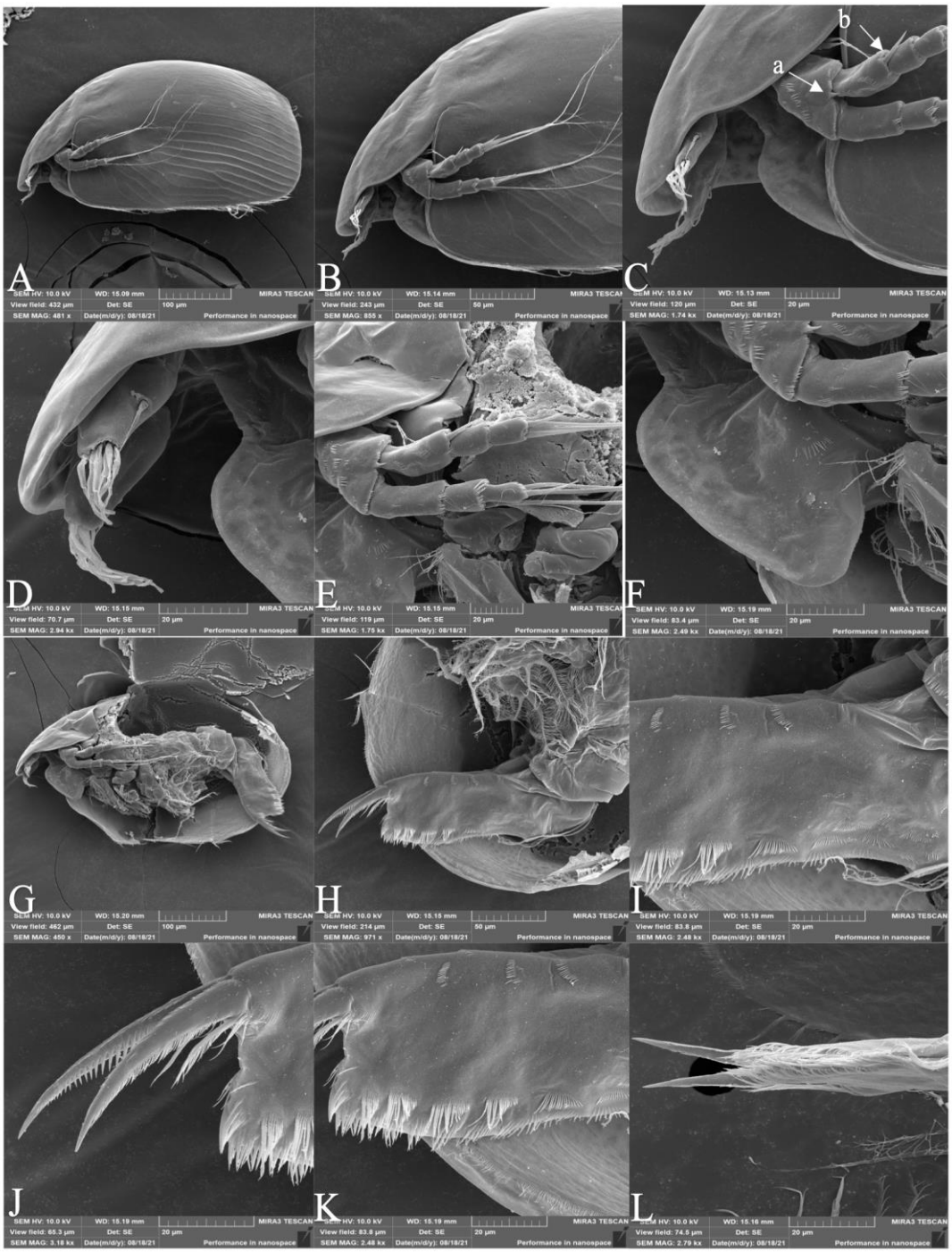

Figure 24: *Coronatella anemae* female picture under SEM. (A) full body structure female, (B) ventral side of the head ,1st antenna and 2nd antenna, (C) head, 1st antenna and 2nd antenna (*a.* small spine in basipod, *b.* exopodite with short spine), (D) 1st antenna with antennule, (E) 2nd antenna with basipod, endopodite and exopodite, (F) labrum, (G) full structure of interior limbs, (H) postabdomen, (I-K) lateral fascicles five to seven groups in postanal portion, consisting of over 15 slender spinules in each group, parallel to each other, of seemlier thickness and slightly increasing in size distally, (L) dorsal view of claws

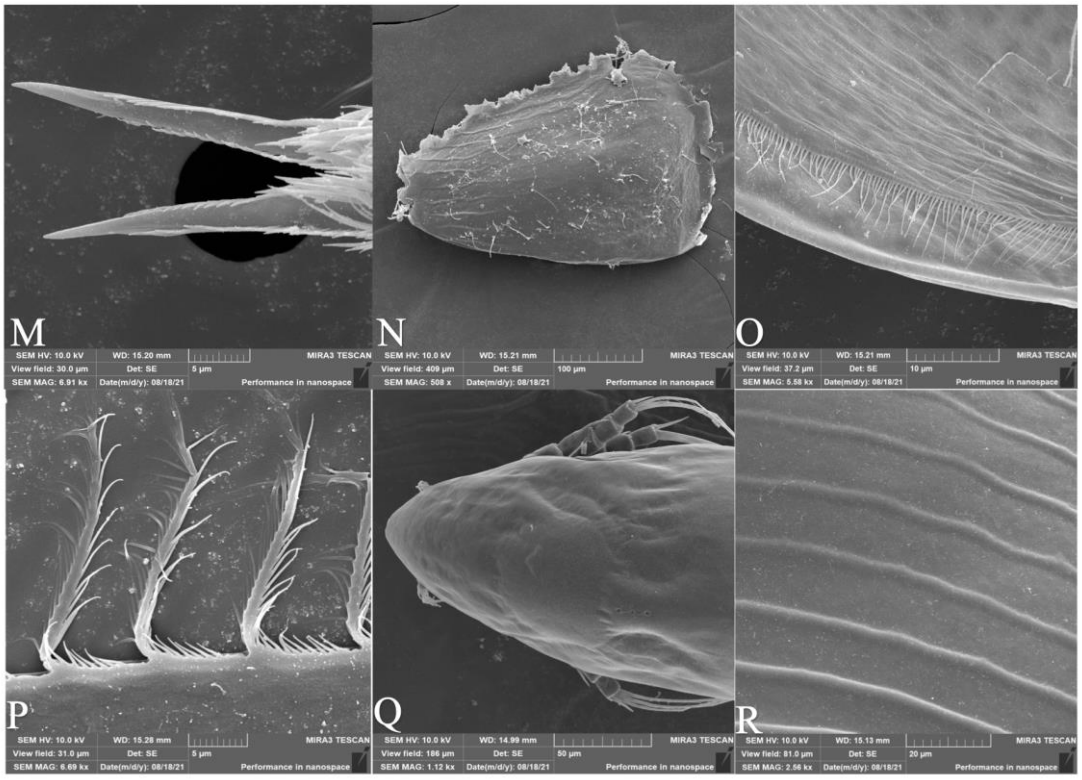

Figure 25: SEM continuation of *Coronatella anemae* female. (M) claws dorsal part, (N) ephippium, (O-P) setae decreasing in size towards the postventral corner and followed by a small spinules not arranged in a group, (Q) head sheld with the dorsal three pores, (R) valves pattren

4.3.2 Camera Lucida – Hand Drawing

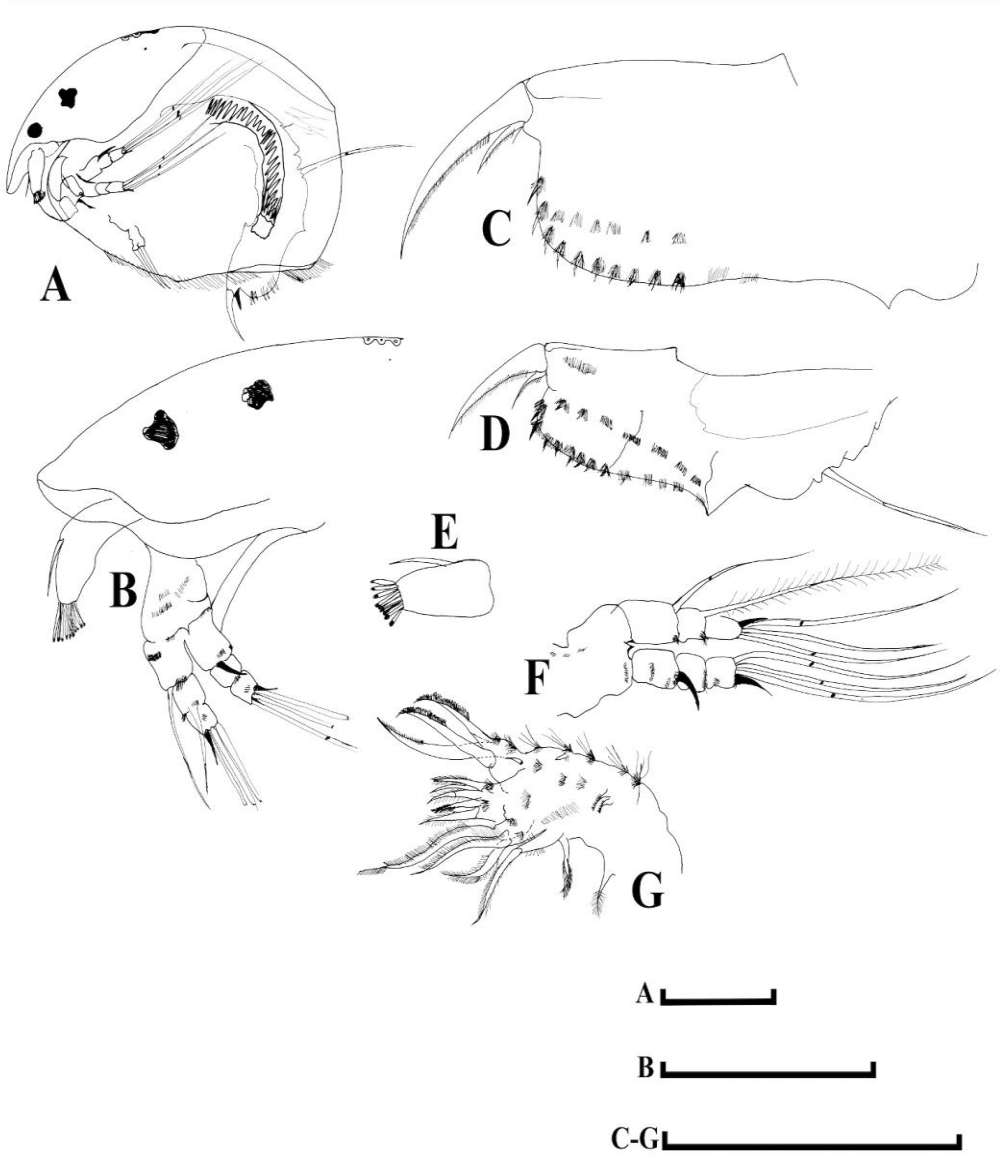

Figure 26: *Coronatella anemae* female. (A) full body structure ventral view, (B) head,1st antenna, 2nd antenna and three pores, (C-D) postabdomen and claws, (E) 1st antenna with antennule, (F) 2nd antenna with basipod, endopodite and exopodite, (G) limb I. Scale bar denotes 0.054 µm (A-B), and 0.141 µm (C-G)

4.3.3 Molecular Analyses

The phylogenetic tree resulted from the COI sequence of *Coronatella anemae* is showing lack of uploaded gene sequence at the gene bank. In fact, its phylogenetic tree is not matching the morphological taxonomic ranking reached in the present study as shown in Figure 27.

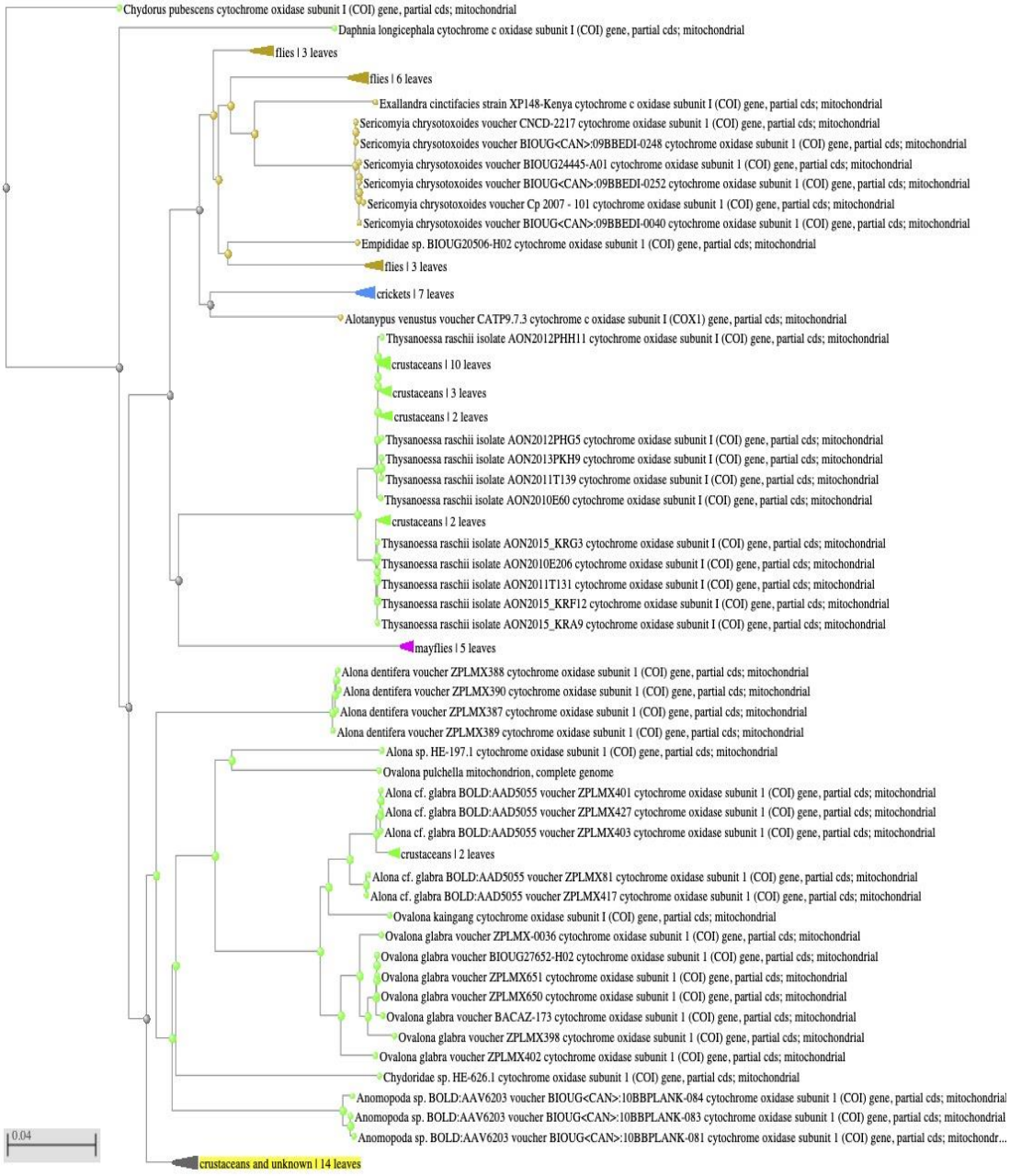

Figure 27: Phylogenetic tree resulted from the COI sequence of *Coronatella anemae*

4.4 Anthalona Mediterranea

Anthalona mediterranea, has two main head pores (Figure 28 H, and Figure 29 H) they are relatively small and connected by Chitin ring. As well as two lateral cauliflower like sacks (Figure 28 G). *Carapace* has marginal setae 42–56 is divided into two groups: the anterior group is long, the median and posterior groups are half as long, and the posterior setae are slightly longer than the median setae. Setae do not decrease in size as they approach the posteroventral corner, but they do stop abruptly and are followed by fine setules. *Labrum* of *A. mediterranea* is different from the one of *Alona sp.,* on the labral keel, there is no proximal denticle but a sparse cluster of minute setules that differentiate *Anthalona* from *Alona* (Figure 30 D). Deferential diagnosis *A. mediterranea sp.,* can be recognized by Second antennae, labrum, post abdomen and first limb hocks shape (ODL). 2nd antenna (Figure 29 C-D, and Figure 30 H) first exopod seta does not extend beyond the terminal exopod segment; the second exopod seta is three times longer than the first. Fine spinule groups on the first and second exopod segments are not too thickened. Main terminal spines on endo- and exopods fully developed, each as long as their apical segment, exopod spine may be shorter. Terminal setae on the antennal exopod are like those on the endopod and have lengthy setules. These swimming setae are short in comparison to the body, not (or barely) extending beyond the dorsum. While the post abdomen the preanal angle is the broadest, and the dorso-distal border is rounded.

The anal and postanal margins together are shorter than the ventral edge. Anal margin is longer than postanal margin and preanal margin is the same length. The anal margin is somewhat concave, whereas the postanal edge is slightly convex. About half of the claw width at the base of the distal embayment (dorsal to basal claw). First limb

is also an indicator as the ODL hooks uneven ejector are quite big (Figure 29 L, and Figure 30 I-K) and in male (Figure 31 G) (Van Damme et al., 2011).

4.4.1 Light Microscope Identification

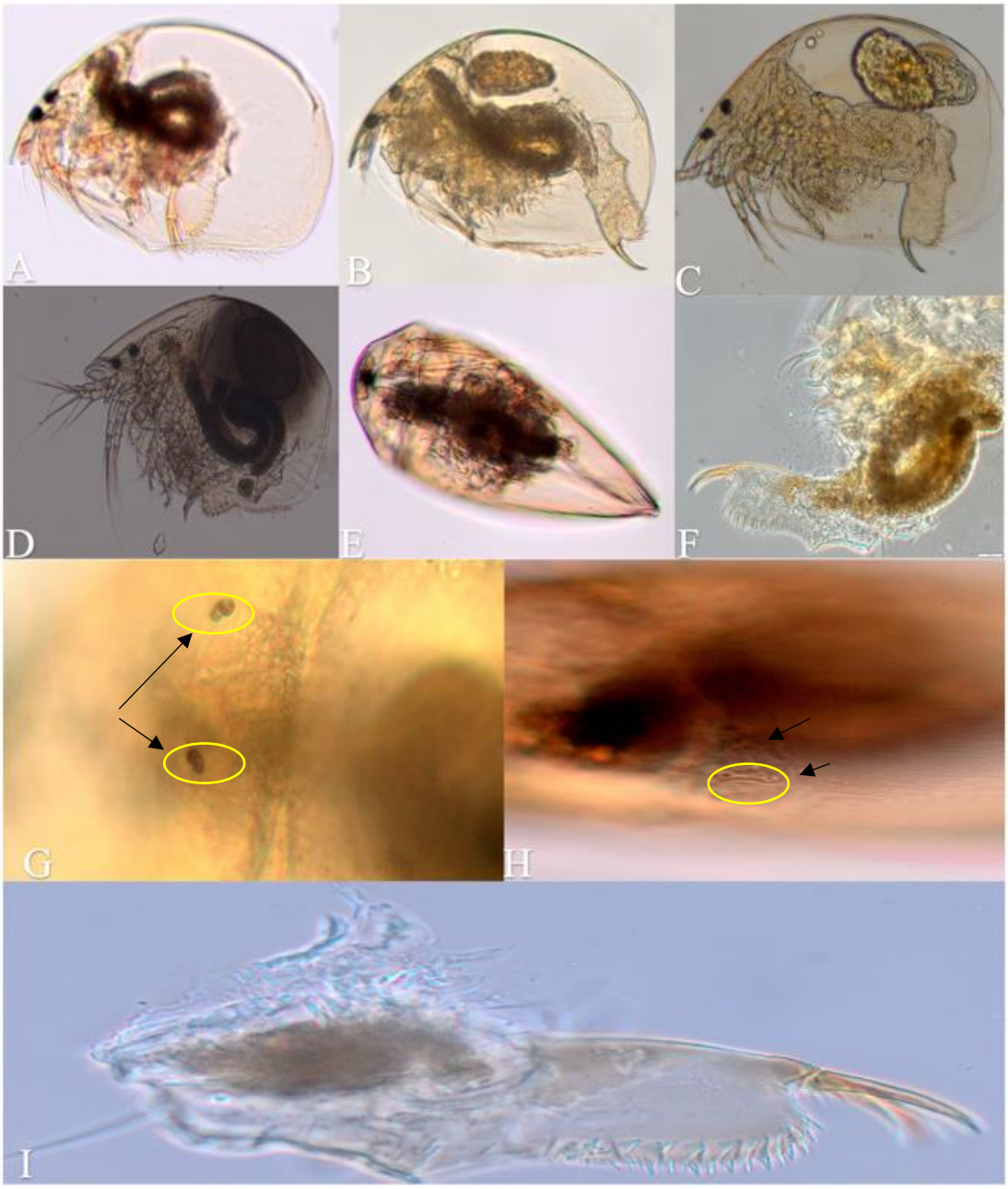

Figure 28: *Anthalona mediterranea* female. (A) female adult full body ventral view, (B-C) ventral view of parthenogenetic female, (D) ventral view of female in sexual stage, (E) posterior view, (F) post abdomen attached with all limbs, (G-H) posterior view of head two pores, (I) post abdomen

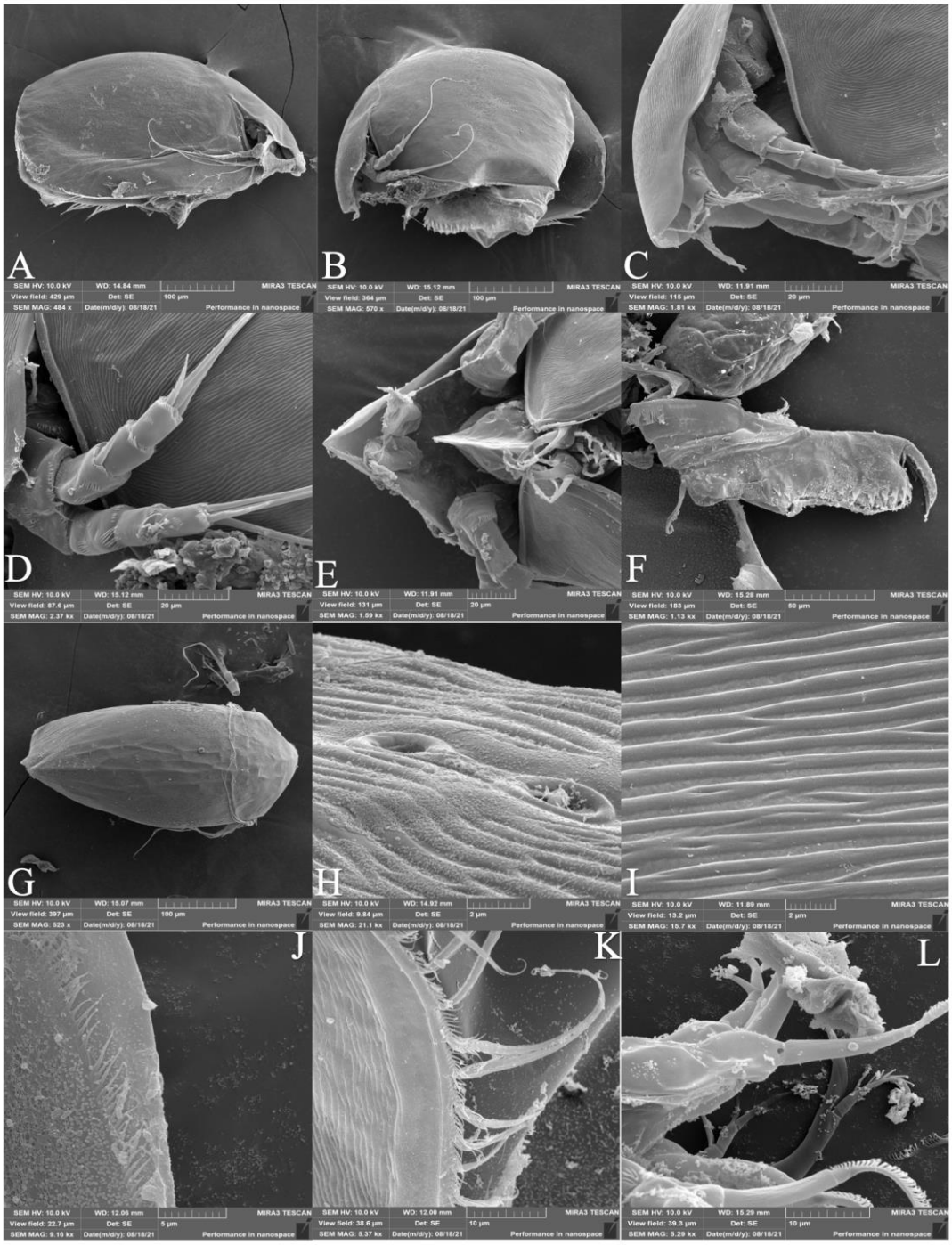

Figure 29: *Anthalona mediterranea* female pictures by SEM. (A-B) female adult full body ventral view, (C) head, 1st antenna and 2nd antenna, (D) 2nd antenna with basipod, endopodite and exopodite, (E) lateral view of head, labrum and 1st antenna, (F) post abdomen, (G) faint dorsal keel in dorsal view, (H) two main head pores, (I) carpus pattern, (J-K) carpus setae aligning the edge of valve, (L) limb I, ODL

4.4.2 Camera Lucida – Hand Drawing

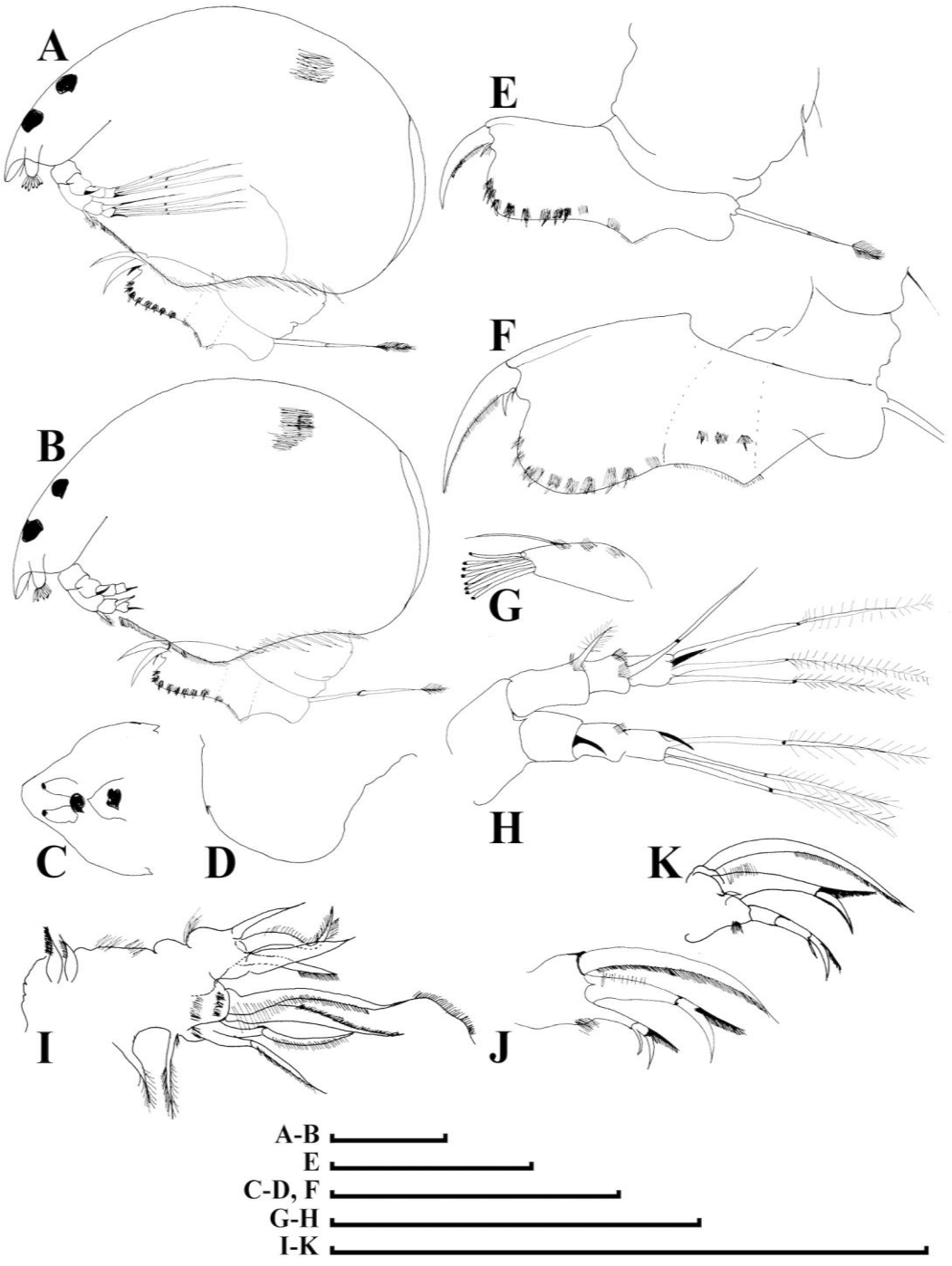

Figure 30: Hand drawings of *Anthalona mediterranea* female. (A-B) female adult full body ventral view, (C) dorsal view of head, 1st antenna and labrum, (D) labrum, (E-F) postabdomen and claws, (G) 1st antenna with antennule, (H) 2nd antenna with basipod, endopodite and exopodite, (I) limb I, (J-K) ODL. Scale bar denotes 0.054 µm (A-B), and 0.141 µm (C-K)

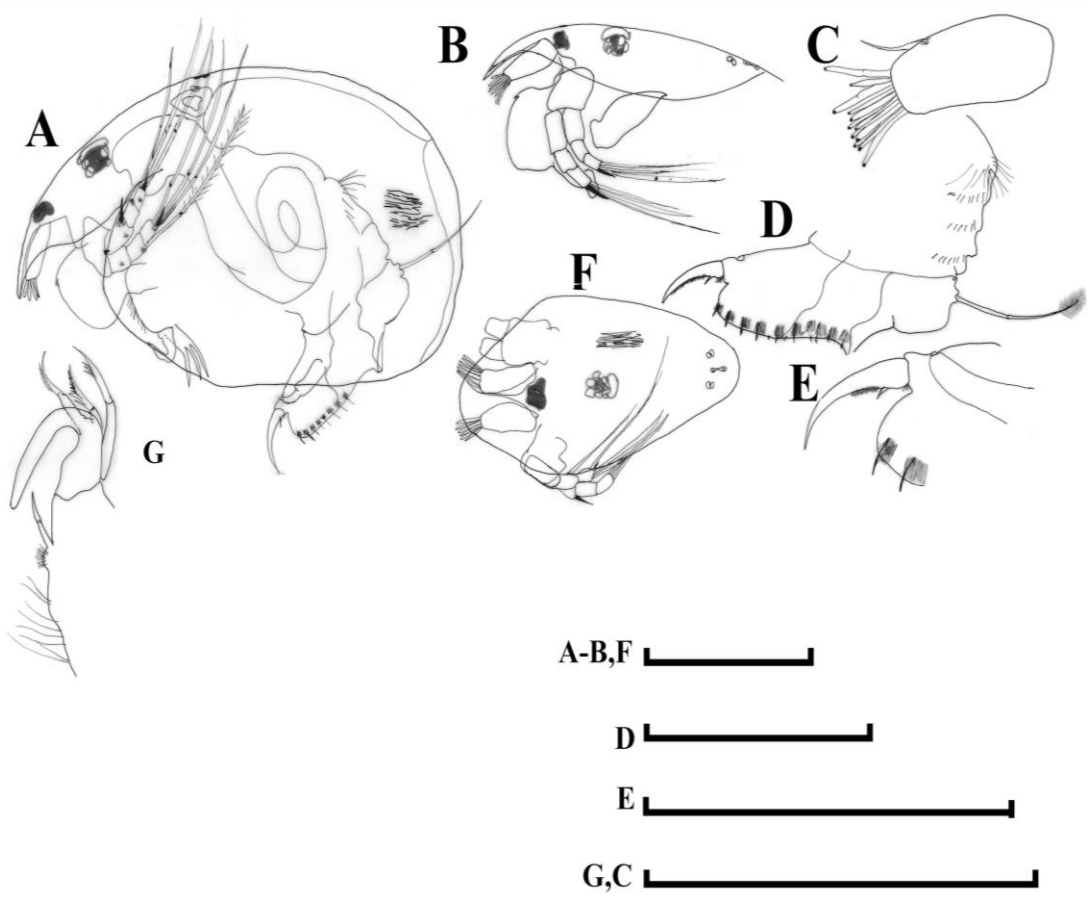

Figure 31: Hand drawings of *Anthalona mediterranea* male. (A) male adult full body ventral view, (B) ventral view of head, 1st antenna ,2nd antenna and labrum, (C) 1st antenna with antennule, (D-E) post abdomen and claws, (G) male limb I. Scale bar denotes 0.054 µm (A-B, F), and 0.141 µm (C-E, G)

4.4.3 Molecular Analyses

The phylogenetic tree resulted from the COI sequence of *Anthalona mediterranea* is showing lack of uploaded gene sequence at the gene bank. In fact, its phylogenetic tree is not matching the morphological taxonomic ranking reached in the present study as shown in Figure 32.

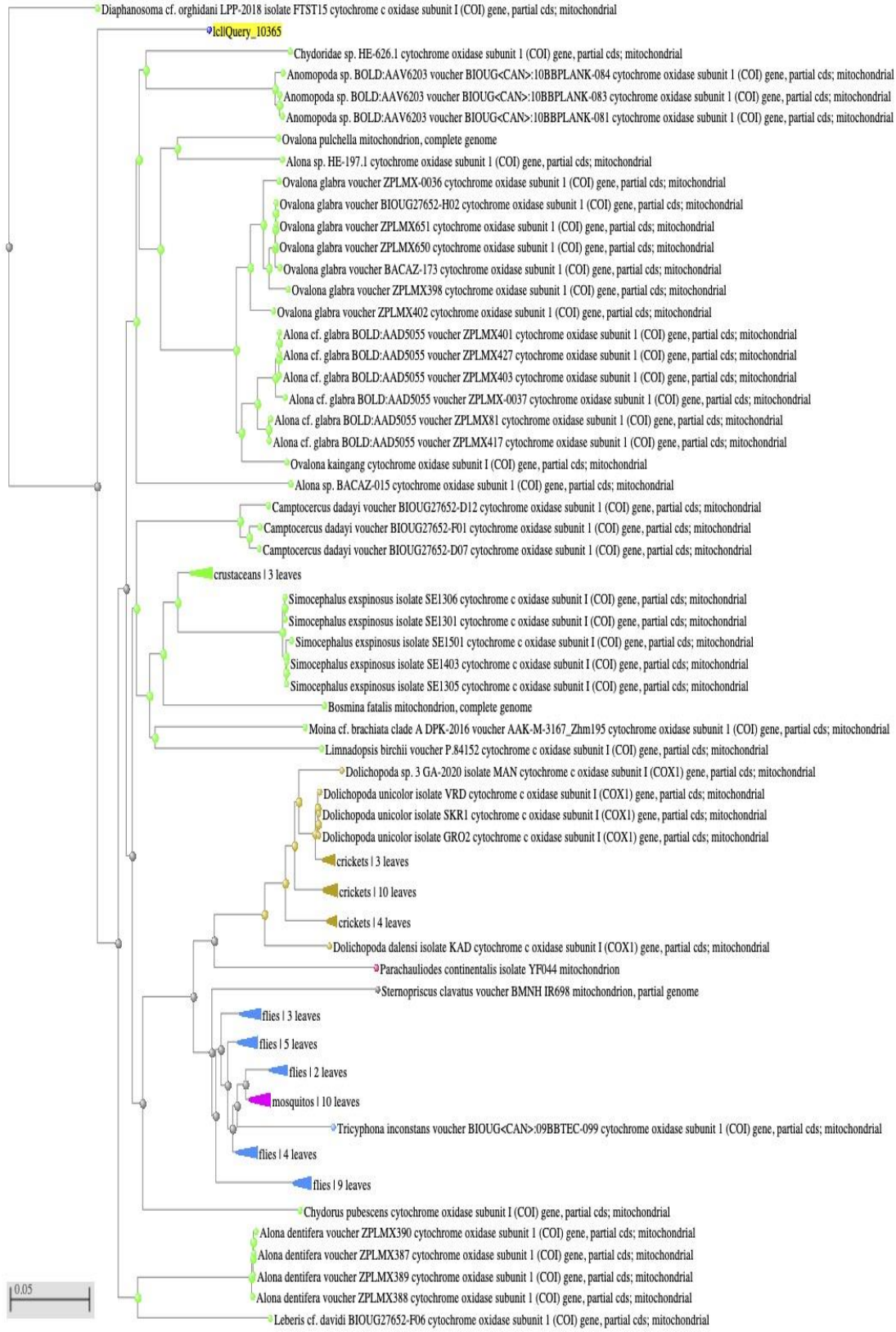

Figure 32: Phylogenetic tree resulted from the COI sequence of *Anthalona mediterranea*

4.5 Daphnia Similoides

This species, identified by Hamza et al. (2018), having a lot of debates. In their study the authors depended on the morphological identification under stereo microscope and on Molecular sequence maximum score of sequence similarity of other *Daphnia* species with gene sequences found in the Gene bank (Figures 33-39). However, in this study further morphological detailed analyses have shown that this is not the typical *D. similoides* described in literatures. Here below, few information can be given for its preliminary obtained results, so it has been decided to go through Full Genome analyses for the suspicious of a new *Daphnia* species identification. This will need more time and needs collaboration between experts in both morphological taxonomists and molecular full genome analyses ones. It has been decided by the supervisor of this study, to wait until getting a decisive confirmation of the species nomenclature, then a separate article with both morphological and molecular features will be published.

4.5.1 Light Microscope Identification

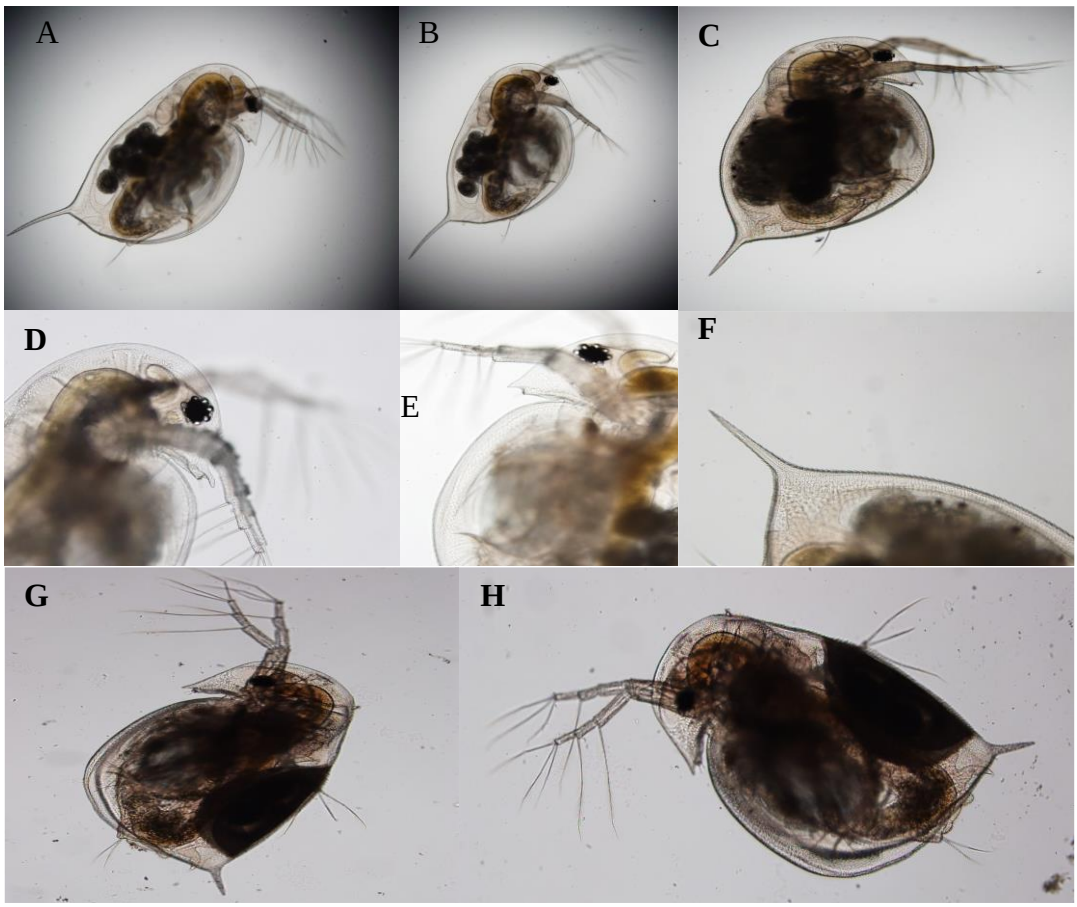

Figure 33: *Daphnia similoides* female. (A-C) full adult parthenogenetic female body lateral view, (D-E) lateral view of head and 1st antenna and 2nd antenna female, (F) coudal spine, (G-H) female sexual stage (as per Hamza et al. (2018))

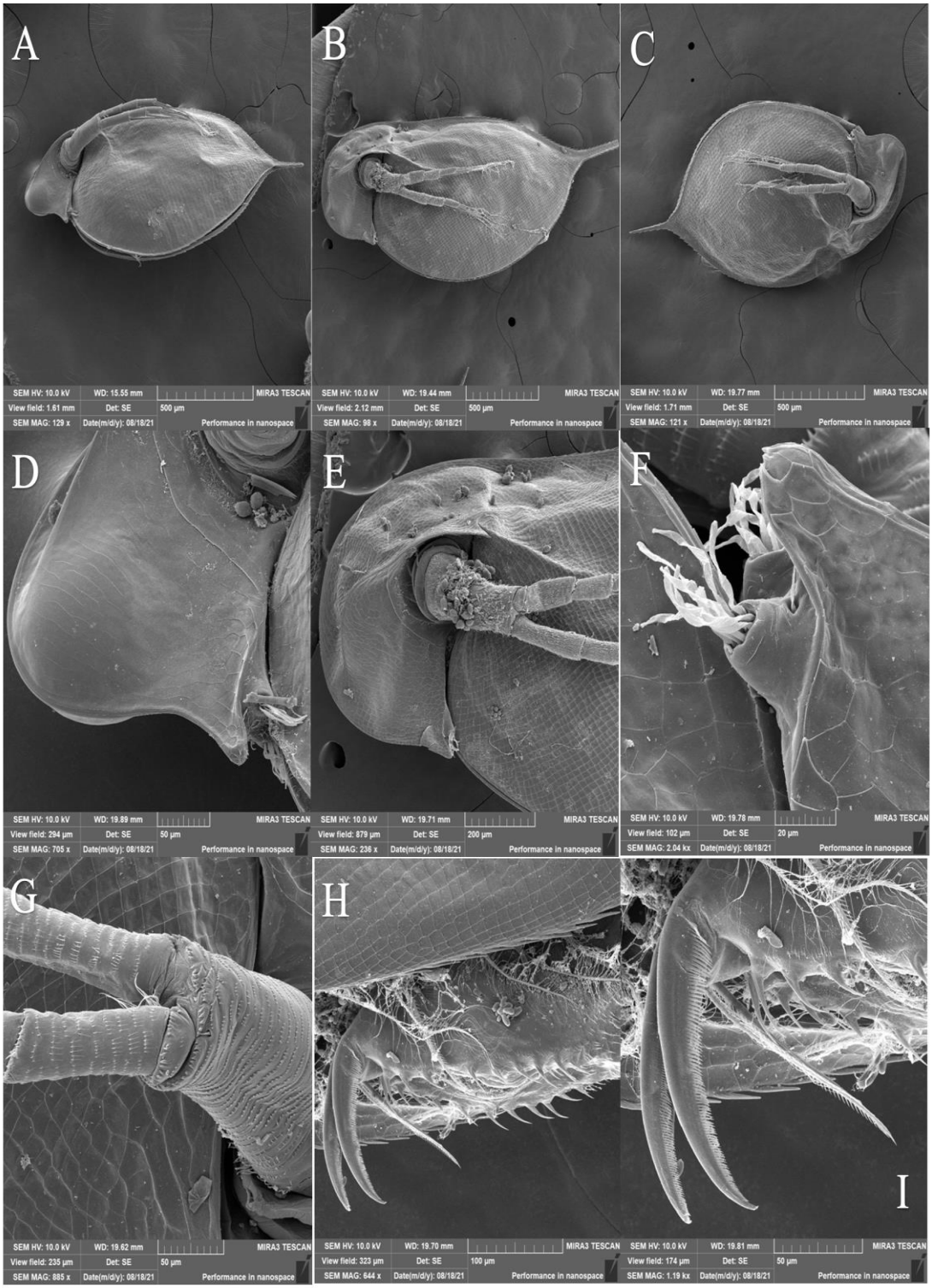

Figure 34: SEM pictures showing *Daphnia similoides* adult female. (A-C) ventral view of full female adult, (D) ventral view of head, (E) ventral view of head,1st antenna and 2nd antenna, (F) 1st antenna, (G) 2nd antenna, (H-I) postabdomen and postabdominal claws

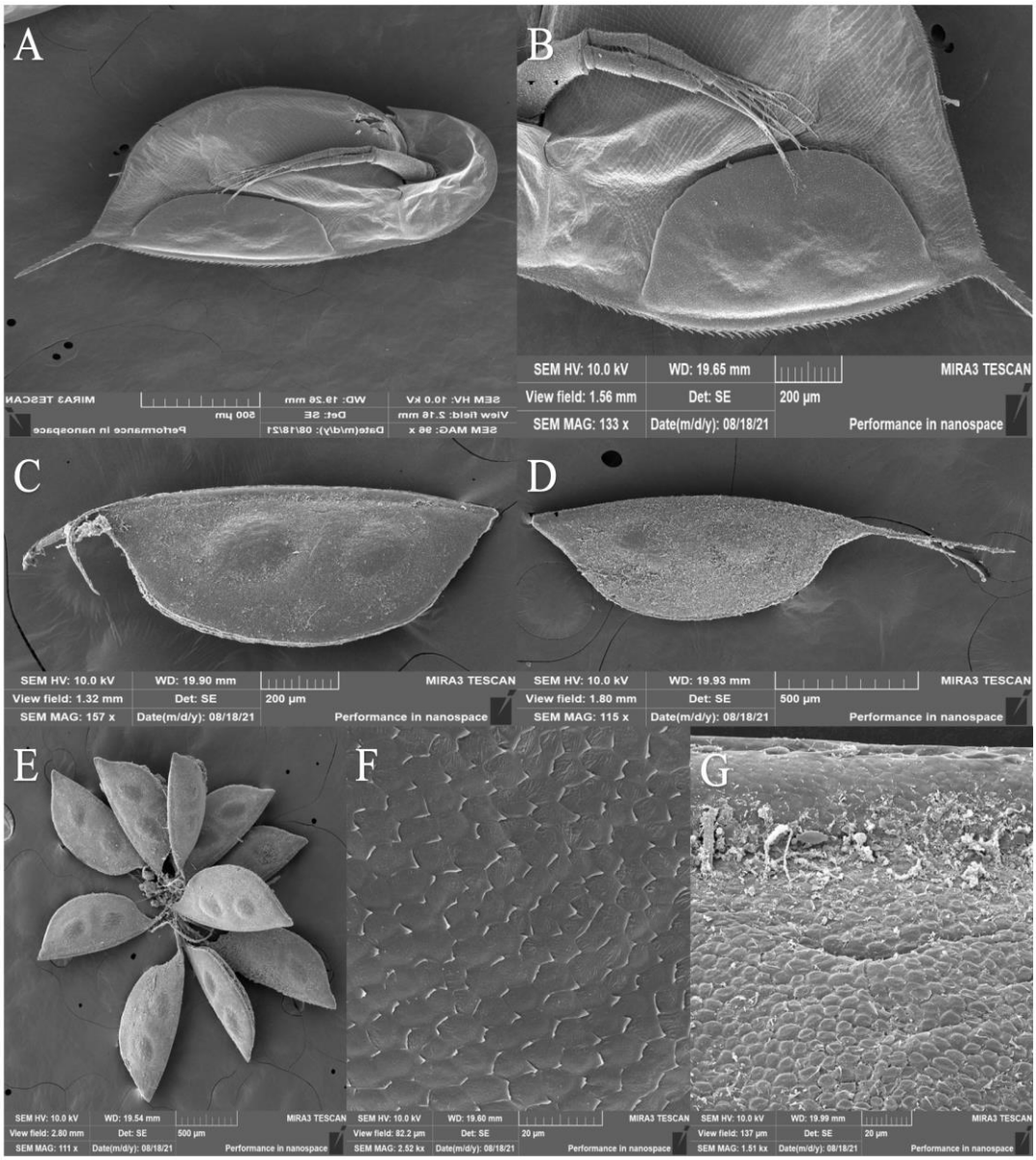

Figure 35: SEM pictures showing *Daphnia similoides* adult female in sexual stage. (A-B) sexual stage with egg in the carpus, (C-D) ventral view of sexual egg, (E) collection of eggs, (F-G) patron on the egg

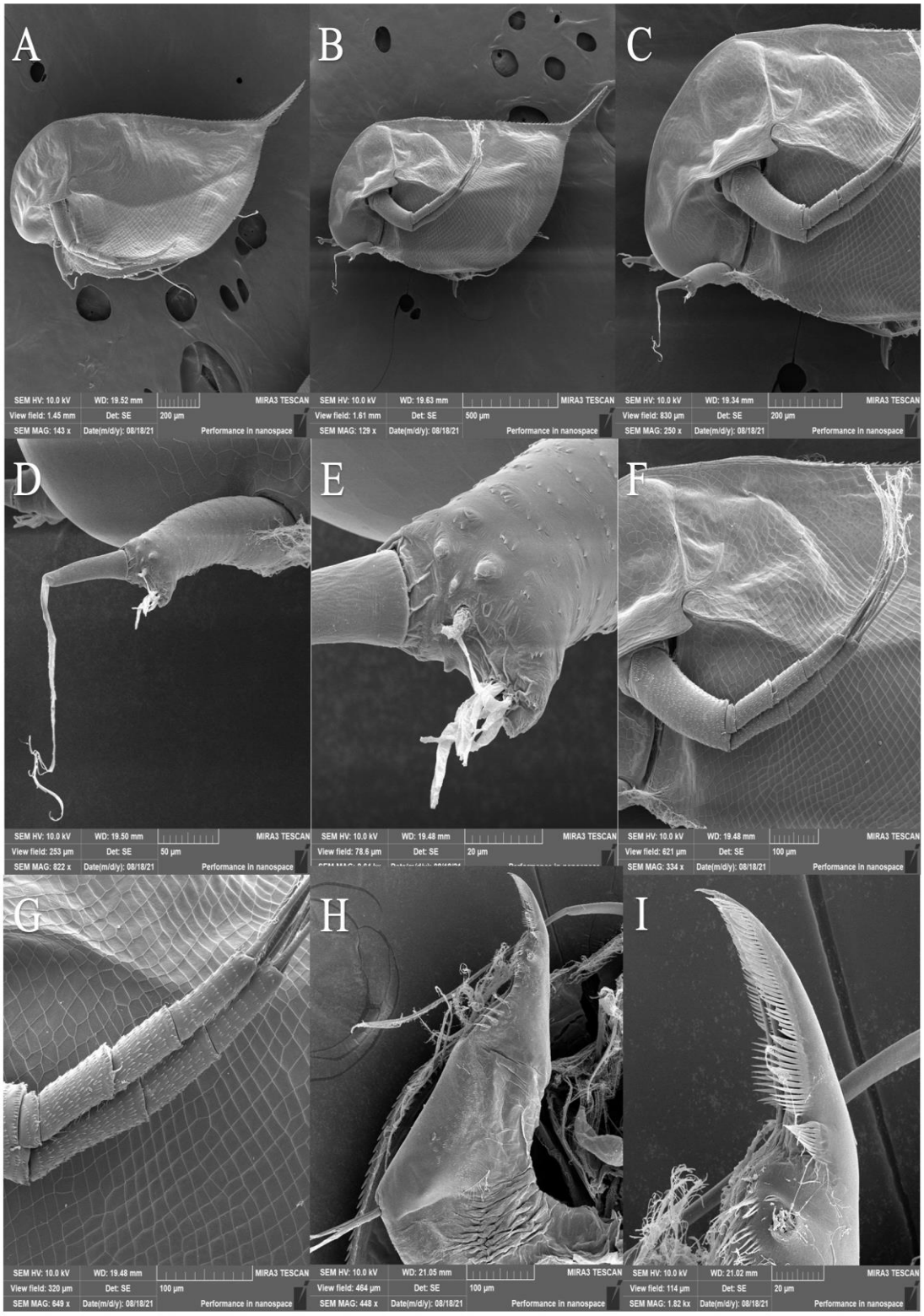

Figure 36: SEM pictures showing *Daphnia similoides* adult male. (A-C) ventral view of male, (D-E) 1st antenna of male, (F-G) 2nd antenna of male, (H-I) postabdomen and postabdominal claws

4.5.2 Camera Lucida – Hand Drawing

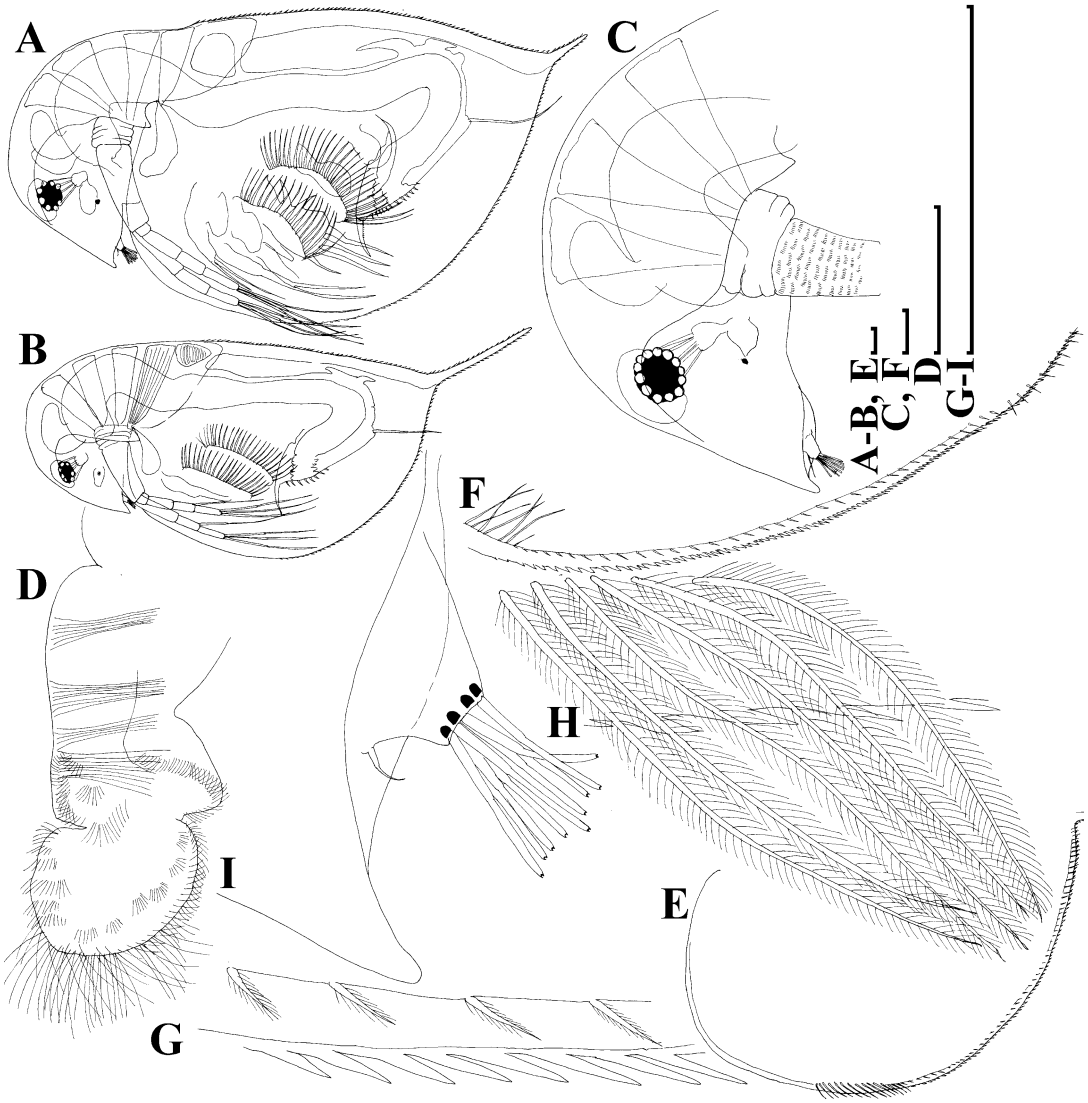

Figure 37: *Daphnia similoides* pictures using camera lucida adult female. (A) ventral view of full female adult, (B) juvenile female ventral view, (C) ventral view of head, (D) Labrum, (E-H) ventral view of the valves, (I)1st antenna. Scale bar denotes 0.015 µm (A-B, E), 0.054 µm (C, F), and 0.141 µm (D, G-I)

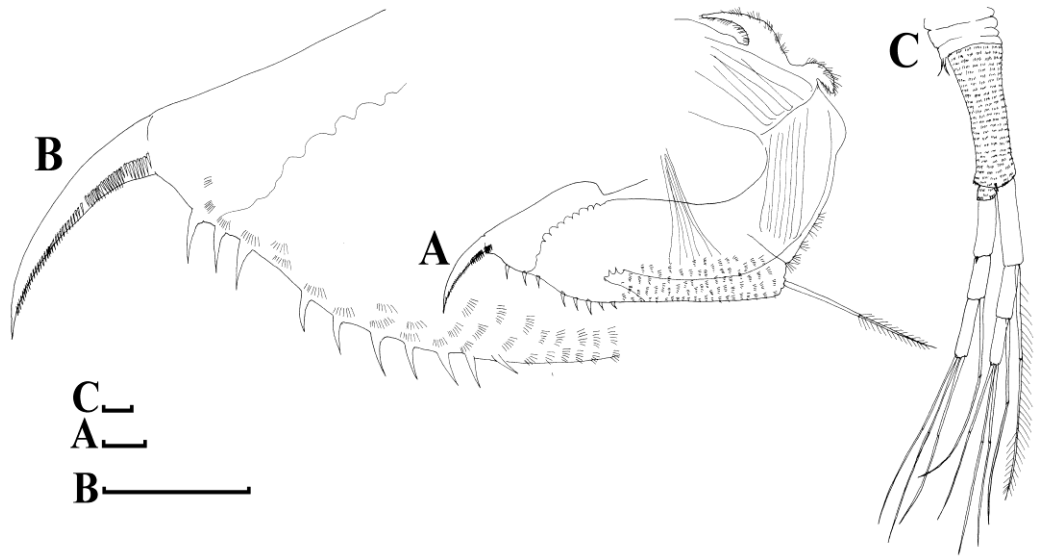

Figure 38: Female *Daphnia similoides* pictures using camera lucida. (A-B) postabdomen ventral view of claws, (C) 2nd antenna. Scale bar denotes 0.141 µm (B), and 0.028 µm (A, C)

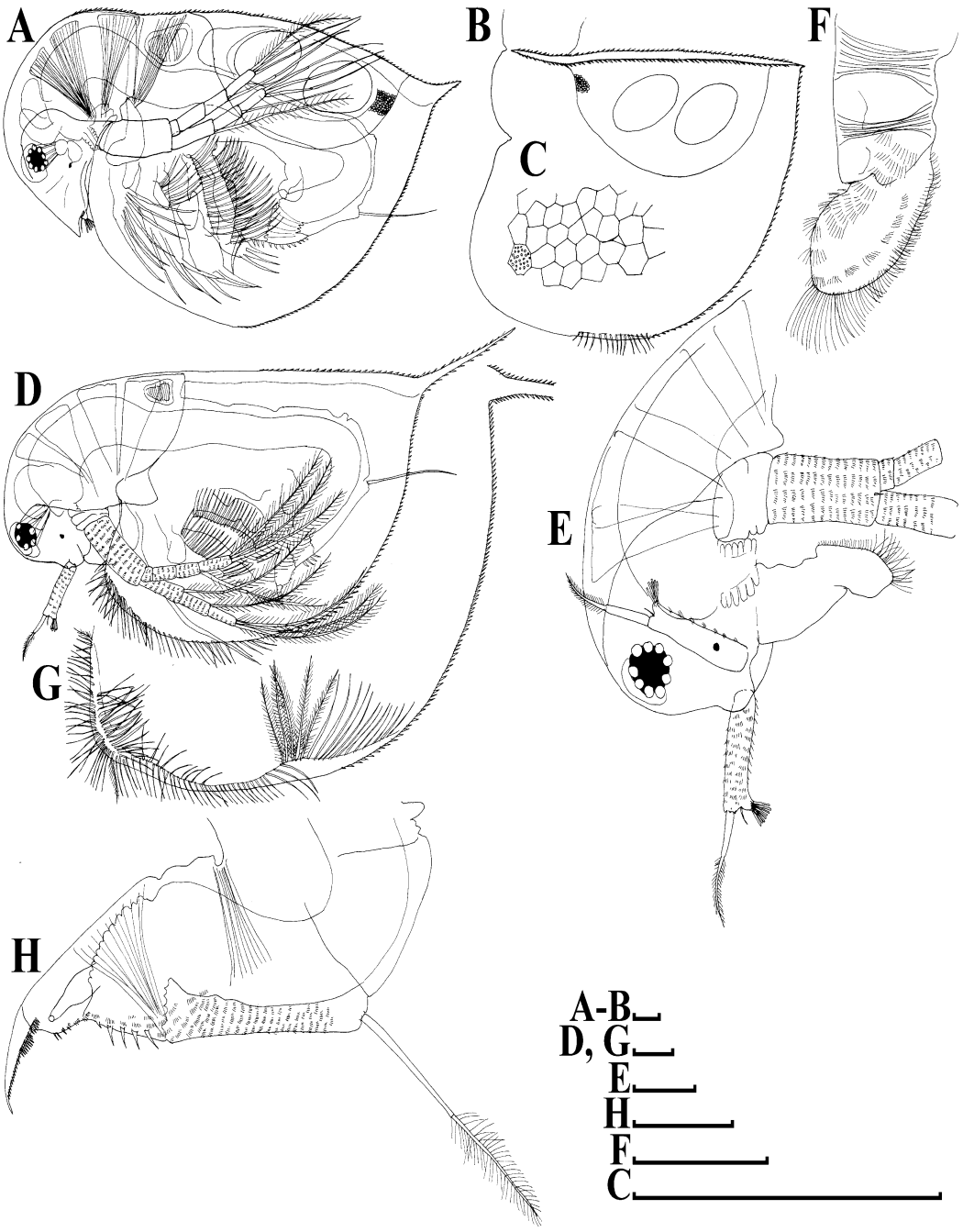

Figure 39: *Daphnia similoides* in sexual stage pictures using camera lucida. (A) Female *Daphnia similoides* in sexual stage carrying the egg in the carpus, (B-C) ventral, valve with the sexual egg, (D) *Daphnia similoides* adult male, (E) head lateral view with 1st antenna and 2nd antenna, (F) labrum, (G) ventral, postero-ventral and posterior portion of the valve margin, (H) postabdomenal claw. Scale bar denotes 0.015 µm (A-B, D, G), 0.028 µm (E, H), and 0.141 µm (F, C)

4.5.3 Molecular Analyses

The phylogenetic tree resulted from the COI sequence of *Daphnia similoides* is showing lack of uploaded gene sequence at the gene bank. In fact, its phylogenetic tree is not matching the morphological taxonomic ranking reached in the present study as shown in Figure 40.

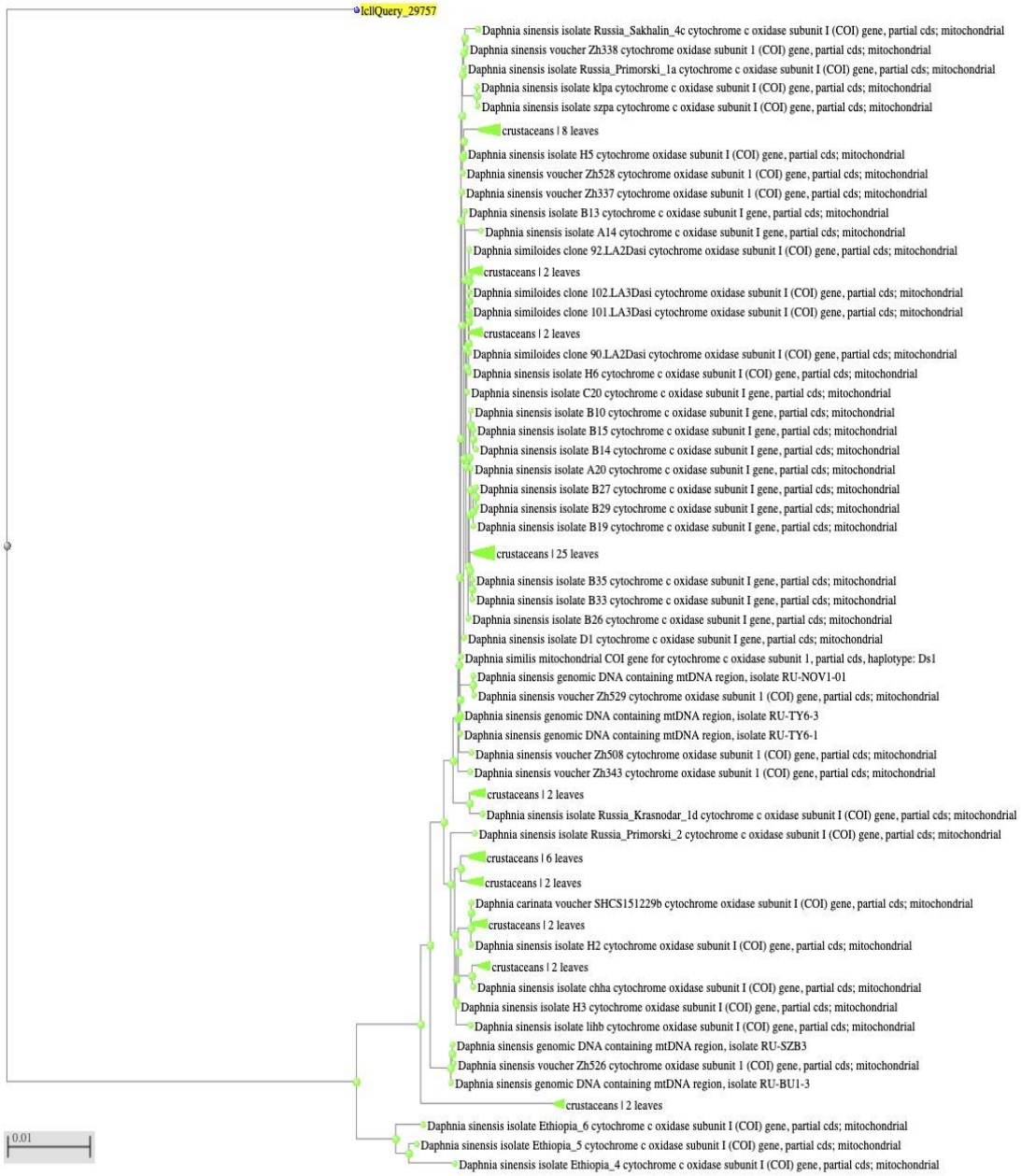

Figure 40: Phylogenetic tree resulted from the COI sequence of *Daphnia similoides*

In General, by using NCBI Blast engine searching for the nucleotide fragment to figure out the identification of Cladocera species identified in the present study within the databank are shown in Table 5. It is worth mentioning that the listed results in Table 5 are based on the DNA extraction and the COI sequence using the Zooplankton primer (ZplakF1_t1; ZplankR1_t1), mentioned by Prosser et al. (2013).

Table 5: Molecular identification result using Blast. NCBI (Zplank F = Forward sequence and Zplank R = Reverse sequence results)

	Zplank_F					Zplank_R				
Sample #	Sequence Code	Description	Scientific Name	Max Score	Per. Ident	Select for downloading or viewing reports	Description	Scientific Name	Max Score	Per. Ident
1	Select seq KC479042.1	Moina micrura cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	*Moina micrura*	865	90.09%	Select seq KC479042.1	Moina micrura cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	Moina micrura	865	90.00%
2	Select seq MK959354.1	Ceriodaphnia cornuta clone TH cytochrome c oxidase subunit I (COI) gene, partial cds; mitochondrial	*Ceriodaphnia cornuta*	865	98.96%	Select seq LC215462.1	Ceriodaphnia cf. cornuta WM-2017a mitochondrial COI gene for cytochrome c oxidase subunit I, partial cds, isolate: Ccor_sakaide03	Ceriodaphnia cf. cornuta WM-2017a	826	98.92%
3	Select seq EU701971.1	Alona dentifera voucher ZPLMX387 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	*Alona dentifera*	619	83.92%	Select seq EU701968.1	Alona dentifera voucher ZPLMX390 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	Alona dentifera	651	84.69%
4	Select seq EU701971.1	Alona dentifera voucher ZPLMX387 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	*Alona dentifera*	604	83.94%	Select seq EU701968.1	Alona dentifera voucher ZPLMX390 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	Alona dentifera	656	84.84%
6	Select seq MG544039.1	Daphnia similoides clone 103.LA3Dasi cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial	*Daphnia similoides*	865	90.74%	Select seq MG544039.1	Daphnia similoides clone 103.LA3Dasi cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial	Daphnia similoides	861	90.51%
7	Select seq EU701970.1x	Alona dentifera voucher ZPLMX388 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	*Alona dentifera*	617	84.89%	Select seq EU701971.1	Alona dentifera voucher ZPLMX387 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	Alona dentifera	616	84.39%

The identified five species in the present study and their sampling locations have distributed geographically on the territorial map of the UAE as shown below in Figure 41.

Figure 41: Distribution of the identified Cladocera species, during the present study, according to their geographical sampling locations of the UAE territory

Chapter 5: Discussion

Wetlands known as the most productive ecosystems. They contain permanently or seasonally flooded freshwater environments such as lakes, rivers, marshes, estuaries, lagoons, mangroves, and reefs and they are utilized for hydropower, they give raw materials and medications, they also reduce flooding, protect coastlines, and sequester carbon (Gardner & Finlayson, 2018).

Yet, some evidence suggest that the value of wetlands may be significantly diminished when they are managed without proper expertise. Globally, wetland losses are monitored by the Ramsar convention, an international body founded in 1971 in Ramsar, Iran, which compiled a list of at least 1060 wetlands of worldwide with many of them under severe stress. Where few nations have the funding for proper conservation or restoration, this list gives support-in the form of international recognition-for local operations aiming to prevent wetland losses (Al Dhaheri, 2004). UAE's water supply was heavily reliant on main aquifers' groundwater output. Groundwater output is dependent on the quantity of rainfall, which is quite limited. Water resources are being used at a pace that exceeds their natural replenishment. When there is an imbalance in the supply and demand of water, groundwater quality deteriorates, and coastal regions are exposed to saltwater intrusion. There is a lack of traditional water supplies, and desalination facilities have been constructed to accommodate the increased demand for water for both home, agricultural, and industrial use (Parimalarenganayaki, 2021). In addition, wastewater treatment facilities are being built around the nation to minimize the need for groundwater and even the need for expensive desalinated water production to be used in agriculture. In order to increase groundwater storage and meet its rising demand, significant efforts

were made to examine and manage water resources, such as the creation of dams and rainwater harvesting projects have received a lot of interest in the United Arab Emirates (Murad, 2010). There are several benefits to dam construction, including protecting against floods, reducing the danger of flooding, and boosting groundwater supply. Latest study showed the great efficiency of dams in storing and replenishing the groundwater as mentioned by Parimalarenganayaki (2021). According to isotopic fingerprints, 20 to 40% of the water held by the Wurrayah and Tawyeen Dams in the UAE was effectively returned into the aquifer. Although many dams have built and many studies have been done in those dams' reservoirs and catchment areas in term of water replenishing as well as in terms of fauna and flora found around those new ecosystems, but all the studies were mainly focusing on macro-organisms (Mahmoud et al., 2018). Few studies in the Arabian Peninsula were carried to investigate the few freshwater and wetlands ecosystems. Those studies were either don by DNA extraction or morphological identification with the only use of light microscope and/or the taxonomic keys without the use proper taxonomic comparisons that depends in a combination of tools and techniques. In Oman for example a study carried by Victor and Victor (2002) studying zooplankton species found in a reservoir at Lalainah village. They have identified two species of Cladocera's as, *Daphnia longispina* and *Ceriodaphnia reticulata*. The study just gave the names of the species found without mentioning any details or even a microscopic picture of the species. That is mainly because the study aimed to investigate the dynamic of zooplankton in the arid area reservoirs but not the morphological and the taxonomic features of the zooplankton especially Cladocera. Following that, another study in Oman coastal waters showed another record for Cladocera but in marine waters which was identified as *Penilia avirostris* (Piontkovski et al., 2014). The latest studies in the region was done by

Hamza et al. (2018), which has recorded three species (*D. similoides, D. carinata and Alona dentifera***)** in UAE at dry sediments of Al Shuwaib dam basin. Recently, Aljohani (2019) identified in both Saudi Arabia and Oman a species of chydoridae, but he only was able to mention the genus name (*Pleuroxus sp*.) but was not able to identify the species.

The present study aimed to survey wetlands at UAE and investigating the existing Cladocera organisms at some of its ecosystems. The obtained result showed that there is a great chance of finding more different Cladocera species not only at the UAE territory but in the territories of the different countries located in the Arabian Peninsula. In fact, the present study that covered only 10 locations have resulted in the finding of 5 new records to be added to the previous record of Cladocera species done by Hamza et al. (2018).

In this study sampling locations were chosen based on their accessibility, where most dams and wetlands are surrounded by mountains and their basins can't be reached unless the premotion from authority is obtained. Samples from basins that has contained water were easy to sample by plankton nets and the isolated species were easy to culture. However, sediments and/or dry sediments samples were more complex. Although, the first method used in this study to culture and hatch eggs from the samples by Onbé (1978) is the widely used method in dry sediments, it was unsuccessful for the samples collected in the present study. That maybe due lack of knowledge in the shape and the size of the resting eggs, as several mesh size and sieving were used without considering the size of the resting egg. On the other hand, the second method showed more success in term of hatching as the sample sediment was socked in the bottled drinking water for several weeks till the hatching species was observed. This method was mentioned by Hamza et al. (2018), and they were able

to get resting eggs execution and hatching of Cladocera cysts from the dry sediment core collected from Al Shuwaib dam basin at Al-Ain city (Abu Dhabi Emirate, UAE). When it comes to the study of freshwater microcrustaceans such as water fleas and copepods, DNA barcoding has proven to be an essential tool for researchers, in confirming the species identity. In addition to providing a fast and accurate way for identification, these molecular approaches have also highlighted cryptic species that were later formally described using a more integrative approach and have been utilized for studies on phylogeographic distribution and to explain speciation processes. These novel methodologies and the discovery of unexpectedly restricted distributions of many microcrustaceans and other taxa have resulted in a surge in interest in microcrustaceans in recent years. Despite DNA barcoding's attractiveness as a technique for studying biodiversity and distribution in zooplankton species it has been uneven in this group's success with cytochrome c oxidase amplification (COI or COXI). This could be due to the fact that there is not a specific prim-er. Where, it is currently common practice to use 'Folmer' or 'Folmer-tailed' primers when amplifying COI in copepods and Cladocerans (Prosser et al., 2013). In fact, in the present study, the modified primer described by Prosser et al. (2013), was very successful at both DNA extraction and its sequence compared to the classical common primers used at molecular laboratories.

In this study, both morphological and molecular different techniques have been used to reach accurate identification of the isolated five (5) Cladocera species.

For, *Moina micrura* in this study was easy to find at the basin of Kholaiban Dam at Masfut area, where the dam was at the period of collection of rains and still has water. Kholaiban Dam Masfut located at Ajman Emirate, near a village with mixed population and located in a valley surrounded by mountains, and it has an easy access

for human, cars and animals. *M. micrura* can play a significant role in the industrial level as young *Moina* can be eaten by newly born fry from most freshwater fish species (He et al., 2001).

A wide range of morphological and ecological adaptations has made by *Moina micrura* that considered a cosmopolitan species. Except in cold-temperate zones, it can be found all over the world (Figure 42). It has been found in a variety of environments, including ponds in Europe, East African lakes, temporary pools in the arid Sahel zone of Africa, various Australian inland waters, and tropical brackish fishponds (Petrusek et al., 2004).

Figure 42: Distribution of *Moina micrura* around the world (c.f. Moina micrura Kurz, 1875)

On the other hand, populations of *Ceriodaphnia cornuta* was found in many complex and dynamic aquatic systems, making them ideal as model species for researching the influence of aquatic landscape features on population genetic patterns in aquatic environments (Zhang et al., 2021). In this study *Ceriodaphnia cornuta* was the second species to be identified as they are found in abundant amount in the water

sample found also in Kholaiban Dam Masfut. *Ceriodaphnia cornuta* have been recorded mainly in Australia and near the Arabinan Peninsula in India as well as in Lake Victoria in Africa as well as in different countries in south America especially in the Amazonian water bodies (Figure 43).

Figure 43: Distribution of *Ceriodaphnia cornuta* around the world (Moina micrura Kurz, 1875)

Differently, due to the lack of knowledge and information about the new species of *Corntella anemae* and *Antalona mediterranea* they were identified as the same species *Corntella as* mentioned in the previous Table 1. The taxonomic comparisons between *C. Anemae* and *A. mediterranea* were very difficult because of the great similarity of their body shape and size, however, with the use of inverted Microscope and SEM distinguishable differences were detected by the differences in labral keel group of minute setules as well as the main pores.

Coronatella anemae was identified by Van Damme and Dumont (2008) who obtained 15 Parthenogenetic females from small pond at entrance of administration building at Sharjah Breeding Centre, Sharjah UAE. In the same study *C. anemae* was

found in Socotra Island (Yemen), and in Sudan freshwater pond. In this study *C. anemae* have been found in three different locations (Figure 44) along with *Anthalona mediterranea* at Masfut Dam (Ajman Emirate), Wadi Ham Dam (Fujairah Emirate), and Wadi Maidaq blue pool (Fujairah).

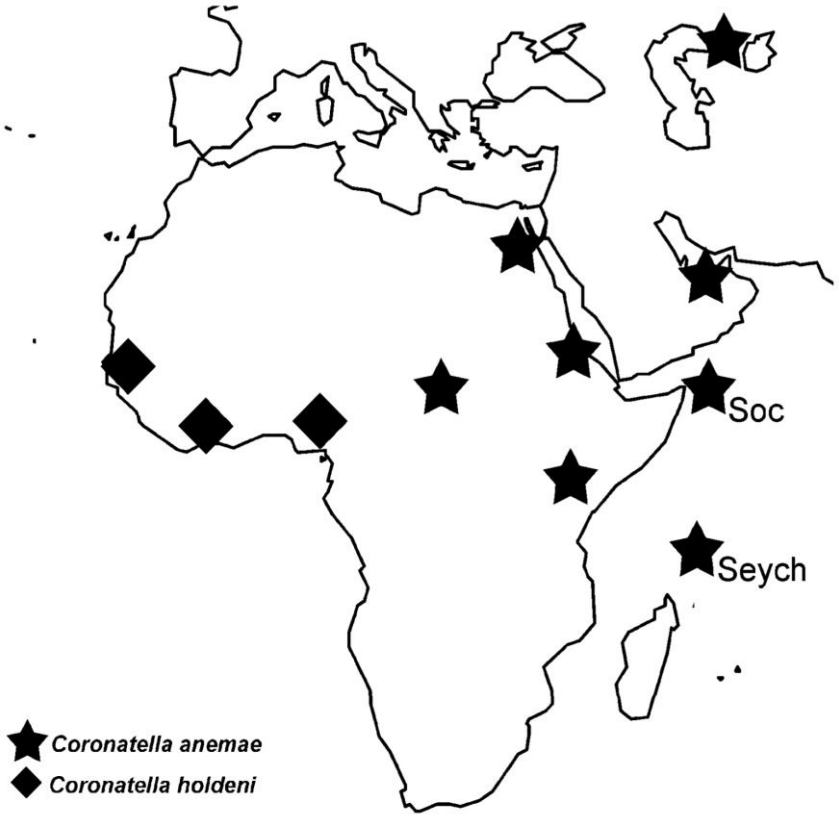

Figure 44: *Coronatella anemae* Distribution (c.f. Van Damme and Dumont (2008))

Anthalona mediterranea (Yalim & Ciplak, 2005), was firstly identified in Socotra Island (Yemen). Later, Van Damme obtained a sample from Wadi Shawkah, Sharjah Emirate, UAE and it was identified and recorded (Van Damme et al., 2011). The presence of A. mediterranea in three different locations, belonging to two different Emirates in the present study, and previously in Yemen, is indicating its distribution in different geographical area not only at UAE but all over the Arabian Peninsula.

The molecular sequence comparison of both C. anemae and A. mediterranea have shown lack of archived molecular sequence information of the genetic features of these two species. In fact, by running a blast on Chydoridae family the results showed different sequences for only one species that belonging to Alona dentifera, which is belonging to the same family, but it has widely identified, also by Hamza et al. (2018). As mentioned by Prosser et al. (2013), sometimes it is difficult to use molecular analyses as a fundamental tool for phylogeny of certain species and the lack of sequence entries in the NCBI may result in inaccurate molecular identification.

For instance, The *Daphnia* samples cultured in the laboratory from another sediments core collected from the same location mentioned by Hamza et al. (2018), has showed cysts execution and growth of dense population, that was molecularly examined by the different primers. The *Daphnia* species mentioned by Hamza et al. (2018) were identified in their study as *D. carinata* and *D. similoides*. However, *Daphnia similoides* molecular results has a great debate between the taxonomic and molecular experts who are acting as advisors of this research. So, they decided to go for further full morphological and full genome analyses since it has shown some variations compared with the described species in literature, which made it a candidate for a new species or a new variety record in UAE.

Many scientists still view the Arabian Peninsula as a desert and arid environment where only a few tolerant organisms can survive. A lot has changed in the previous 50 years, particularly in the economic and trade interchange between the Arabian Gulf nations and the rest of globe. That is because of oil production and trading, but also because of travel, tourism, employment prospects and other business and industrial operations. All modes of transportation, including aircraft, ships, vehicles, trucks, and tankers, are involved in Gulf-bound and Gulf-bound

transportation. Wind and migratory birds, on the other hand, are the most important transporters of Cladocera cysts. It is passively carried without a defined destination all are in forms of soil particles and/or detrital materials of very light weight. The *Cladoceran* hatchlings found in the dam sediments collected for this research might have been carried into the study region in many ways such as by wind, released from the feathers of migratory birds that settle in the dam area after rain, or carried by human through their clothes and shoes as UAE recruited many labors from different countries. In addition to that many infrastructure materials in the past few decades have been carried out in the UAE and imported soil and rock have been brought into the area from different countries.

Al Wathba lake was studied by Al Dhaheri (2004), showed that bird play a great role in dispersing Artemia sp. cyst as the flamingo birds carries the cyst from place to place in their feathers and mud attached to their feathers or legs during their migration. Wetlands in UAE in general are stopover places for many migratory birds for feeding. As the bird stops in water, they can be carrying different species cysts from different countries, and they may be found in the sediment of the wetland. The present study has highlighted that there is more wetland in UAE need to be investigated for the presence of Cladocera species and may be other organisms. Such investigation and new records play a significant role in enriching the biodiversity list of the region at which such species have recorded. Indeed, this type of studies can enrich the biodiversity list of United Arab Emirates and the Arabian Peninsula and add new records as this part of the world which can change the distribution maps of different species around the world. As the new investigation continues the Cladocera distribution Maps will be clearer for the researchers. Moreover, it open new research direction in the region. In fact, there is a direction to build up a research team from the

different countries of the Arabian Peninsula to start a project of Cladocera investigation at different identified wetlands may be newly found at these countries.

Chapter 6: Conclusion

The main aim of the present study was to investigate the presence of Cladocera species within the wetlands of UAE. It succeeded in finding of five species of Cladocera distributed in four Dams' basins in UAE. The recorded species are *Moina micrura, Ceriodaphnia cornuta, Corntella anemae, Antalona mediterranea* and *Daphnia similoides.* Two species were recorded for the first time in UAE which are *Moina micrura, Ceriodaphnia cornuta.* That were recorded in Emirates of Ajman, Masfut dam's basin both species co-exists in the same wetland. While *Corntella anemae* and *Antalona mediterranea* were firstly recorded by Van Damme and Dumont (2008) and Van Damme et al. (2011), respectively. They were found in small pond at entrance of administration building at Sharjah Breeding Centre, Sharjah and from Wadi Shawkah, Sharjah at that time. However, in the present study they were found co-existing in the same dams at Masfut Dam (Ajman), Wadi Ham Dam (Fujairah), and Wadi Maidaq blue pool (Fujairah). The last species is *Daphnia similoides* which was identified by Hamza et al. (2018) and in this study morphological and molecular study have suggested to be considered new species as its DNA sequence was different than *Daphnia similoides* that already archived at the Gene data bank. The study of this species will be continued in further article. Another aim of this study was to investigate the wetland as well as to identify their locations within the UAE territory. A table with dams and wetland's locations and the emirate that they belong to was created. Most of the information was collected from google map as there is no map for all the dams and wetlands in UAE. Not all 114 dams can be found in google map. So, ten locations from the created table were chosen for sampling based on their accessibility and safety of researchers. Samples were then collected and brought back to the lab and extracting

and egg hatching was carried out. Few weeks later some species were identified. Three types of microscopes were used in this study to identify the species morphologically in addition using morphological keys and taxonomic textbooks book with notes on ecology, distribution, methods, and introduction to data analysis. That is in addition to DNA extraction for molecular identification and comparing the obtained results with the existed result in Gene Bank. The present study and it's finding will be the beginning of the investigation of wetland not only in UAE but hopefully it will cover all the Arabian Peninsula countries. It will not stop in only investigation but also studying the effects of the Arabian Peninsula climate on the distribution of this species.

References

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The present study investigated the presence of Cladocera (Crustacea), species in the wetlands found at the Northeastern part of UAE. The study has identified five species by using different modern morphological and molecular techniques to reach the lowest taxonomic ranks of the identified species. The study confirmed the presence of *Daphnia similoides* (Ctenodaphnia), that previously identified by Hamza et al. (2018). Two species were identified as new records at the UAE territory i.e., *Moina micrura* and *Ceriodaphnia cornuta*. While the other two species i.e., *Coronatella anemae* and *Anthalona mediterranea* have found to be previously recorded in other locations of UAE.

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