Rotifer News

A newsletter for rotiferologists throughout the world

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In this issue:

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Editorial: *In this issue*

First of all, I wish you all Happy New Year 2025.

The issue no. 44 covers several interesting items. The cover story (p 2-11) is from Prof. T. Ramakrishna Rao (in short as TR Rao). Prof. Rao was my doctoral degree supervisor and for S. Nandini during her MPhil and PhD programmes. This article gives scintillating reminiscences of a Rotiferologist. The historical account of starting rotifer cultures and taxonomic identification back in four decades ago. I hope many other giants of rotifer research who retired will also contribute similar works to Rotifer News.

A second circular on the XVII International Rotifer Symposium has been released by the president of the organizing committee (Prof. Christina Wyss Castelo Branco). It has details about the venue, registration, deadlines, symposium website, email account etc.

Under the unit recent literature, usually published works of up to 2 years are covered. This is continued in the present issue too (p. 19). In addition, starting from this issue, all of works of eminent rotiferologists are covered with an additional heading "Related Works" with no time limit. The idea is that many rotiferologists work on other groups of zooplankton which have direct relation to rotifers. Secondly, many young rotifer researchers are not interested to search for hidden (old) literature. Therefore, providing a complete list of works from prominent rotiferologists will help young zooplanktonologists to consult appropriate works. To implement this, Prof. Susana José de Paggi's list is included here (p. 14-19).

Prof Brij Gopal, an eminent wetland ecologist loved books. He collected more than 6500 books, some dating back to 1955. After he passed away (Jan. 4, 2021), his daughter, Ms. Sudha Gupta, made a great effort to donate this literature to the Nalanda University (State of Bihar, India). This is a generous donation of valuable literature from Prof. Brij Gopal (see p. 20-21).

My own contribution on citation analysis of selected rotiferologists of Hirsch *h* index with Shannon index (*H'*) and Pielou's evenness (*J'*) has been included in this issue (p 22-30). Feedback from the readers will be included in the next issue.

Rotifer News has been receiving some original contributions for publication (see RN 34: 16-25, 2021). These have been peer-reviewed before publication. However, other news items are not refereed. Whenever, original works appear in any journal or newsletter, there should be a scope for retraction of articles. Therefore, this option is now available for RN too in an unlikely situation.

The next rotifer news issue (no. 45) will be hopefully released during May, 2025.

S.S.S. Sarma
Editor

Reminiscences of a Retired Rotiferologist

T.R. Rao

Email: trrao39@gmail.com

As I enter the autumn of my life in an octogenarian stage, I try to remember my past and recall some of the major highlights of my teaching and research, and a career spanning over 40 years. Many of these memories, like the colors of an old photograph, have faded away over a period of time, but some of them remain so fresh and vivid that it seems like they happened just a few days ago. I have been fascinated by these lovable rotifers for a long time. Over the years, I have developed not just a passion, but one bordering on love for these creatures and it has been my pleasure to work with this group of fascinating creatures.

How Rotifers were chosen as my major research animals.

My first exposure to these rotifers was probably around 1974-75, that is more than half a century ago (!), when I was doing my postdoctoral studies at Hawaii Institute of Marine Biology after earning my PhD from the University of California at Irvine, followed by my first postdoctoral in Canada. There was at this institute a very active Aquaculture group headed by my friend Robert May, and they were trying to raise the Hawaiian fish *moi*, *Polydactylus sexfilis* under aquaculture conditions. This fish is highly priced and therefore commercially very important in Hawaii. They wanted to see if this fish can be raised in aquaculture ponds. One of the stumbling blocks in raising the fish was poor larval survival. Moi larvae were tiny (true of most r-selected marine fishes) and the size of live foods they could utilize depended on the size of their gape. *Artemia* nauplii, the universally used live food for rearing freshwater fish, proved to be too big for moi larvae.

Around that time there was a report of using of rotifers (*Brachionis plicatilis*, I think) as larval food. We wanted to try rotifers as food for *moi* larvae. That was the first time I peeped through a microscope and looked at our favorite animals, the rotifers. Believe me, it was not a love at first sight! I was trained essentially as a marine fish biologist and hardly had an earlier exposure to rotifers.

In 1977 I returned to India. Following a brief stint at a marine institute in the southern part of India I decided to move to the University of Delhi. But moving to Delhi meant giving up marine biology, my specialization. I reluctantly switched to freshwater and started wading through freshwater bodies in and around Delhi looking for research problems to get going.

Around that time (1976) came out a much discussed and highly cited review paper on the evolution of life history strategies by Stephen Stearns. That topic fascinated and appealed to

me as a broad research area that I could take up to start my career at the University of Delhi. If one wanted to study the ecology and evolution of life history traits the experimental animal should ideally be an r-selected species (small body size, short generation time, high fecundity, etc.). I realized that one of the zooplankton species might meet these requirements. Rotifers came to my mind because of my prior familiarity with them. We started collecting zooplankton from local water bodies, lakes, ponds, and backwaters of River Yamuna. I recall we didn't have the right collecting equipment (Plate 1). There was no small boat available that we could use to collect plankton slightly away from the edge of the lake or pond. Often the depth at which we could collect zooplankton was limited by how deep we could go without the risk of drowning! We started making our own small plankton cylinders which were simply a PVC pipe segment (4" dia X 6") to which nylon mesh of different pore sizes (40 – 250µm) was glued. When we started observing the collected zooplankton samples under a microscope, it occurred to us that we need not confine our interest to rotifers alone since two other groups-cladocerans and copepods common in our plankton, were also ideally suited for our chosen research area. Looking at these three groups, it occurred to me that they show three different modes of sexual reproduction-ancestrally asexual bdelloid rotifers, cyclically parthenogenetic cladocerans, and perpetually sexually reproducing copepods. I envisioned a grandiose and long-term plan of studying the comparative reproductive strategies of rotifers, cladocerans and copepods, but that ambitious plan, like many others during my career, never materialized.

Species identification

As our zooplankton collections started revealing an impressive diversity of species, we faced the problem of identifying them to species level. Particularly for rotifers, with only a nodding acquaintance with them earlier, I was no expert in identifying even the most common species. Taxonomic keys were not readily available. If they were, it was very difficult to get the journals where they were published. During those days (nearly 45 years ago!) names associated with rotifer studies were MVSSS Dhanapathi, then a retired college teacher, and later, BK Sharma and R George Michael. Prof. Michael was a limnologist specializing in cladocerans, but he helped us identify common rotifer species based on my drawings sent to him. Other than this, we didn't have any up-to-date keys for identifying the species. Koste's two-volume treatise, the rotiferologist's '*vademicum',* was a luxury at that time, which our university library couldn't afford to buy (How ironic it is that now I have on my laptop a *pdf* version of Koste's treatise, no longer consulted but saved more like an occasionally opened family photo album!).

With the success of rotifer cultures, especially *Brachionus calyciflorus* and *Plationus patulus* (before *Brachionus patulus*), I began using them as live

Plate 1. During active rotifer research. Left column: 1. Plankton culturing at Delhi University, 2. Plankton meshes routinely used for cultures; 3. Collecting plankton with Ram Kumar in Taiwan. Right column: 1 & 2. Plankton culturing, 3. Field sampling.

feed to larval fish such as common carp and Indian major carps and one of students Ram B Khadka (recently passed away) obtained his doctoral degree with the feeding data.

When Sarma joined my lab initially as a research assistant and later as a doctoral student he brought with him his interest in taxonomy. While working in my extramurally funded research project, he started collecting plankton from different water bodies in and around Delhi and identified rotifers to the extent possible and made camera-lucida sketches. His meticulous and dedicated work soon resulted in a working guide ("Rotifer identification manual") for identification of rotifers, a guide that continued to be helpful to subsequent batches of graduate students in my lab.

In my lab Nandini proved to be as curious, as passionate and as motivated as Sarma, and I was happy that their subsequent marriage had a mutually synergestic effect on their research productivity, particularly after they moved to Mexico.

Consulting journals for the latest literature on freshwater zooplankton was not easy since the university library did not subscribe to many journals due to financial constraints. The university however was able to subscribe to Life Sciences section of a weekly journal called *Current Contents* published by Eugene Garfield. That journal simply listed every week the titles of all papers from relevant journals, which helped us to browse through all the published papers (only titles!) of interest in ecology of zooplankton. We would write to the authors requesting a reprint, for which we had to spend often a lot of money on airmail postage for overseas authors. When we received them, it used to be such a thrill to possess autographed reprints (Somewhere in my reprint collection there must still be one or two reprints signed by JJ Gilbert!). There was during that period a governmental agency which used to help Indian scientists in obtaining photostat copies of published papers not easily available in the country. However, the time taken to get what we wanted through that agency used to be no less than two weeks. Compare our situation in the Eighties with the present-day digital revolution that allows any researcher to access the latest electronic journals and get a *pdf* soft copy or a printout of any paper of interest in no time. It was truly a stone-age technology!

Culture and maintenance of experimental animals

Since we needed live animals for our experiments, we started making efforts to culture them. Now, the problem was how to maintain sustained cultures of chosen rotifers and cladocerans. Uninterrupted supply of their algal food was obviously a prerequisite. First, we had to develop sustainable algal cultures in the lab on a relatively large scale. We experimented initially with species like *Scenedesmus* and *Chlorella* but ultimately *Chlorella* turned out to be our staple zooplankton food. There was an agricultural research institute in Delhi who were maintaining some algal

cultures and also cyanobacterial cultures. With great difficulty, we managed to get a small starter culture of *Chlorella*. An air-conditioned room with fluorescent tube light illumination housed the algal cultures in 10L borosil bottles. Later we acquired a BOD incubator equipped with illumination. indigenous incubators were very unreliable. We would place our algal and rotifer cultures in the incubator and hope that everything would go well. One never knew when the incubator might malfunction, resulting in inside temperature shooting up beyond the optimal range. During the night if the BOD failed or if there was a prolonged power outage most of the cultures got literally cooked by the time anybody arrived in the morning. Such a scenario used to be a nightmare for me during nights. It happened so many times that our precious cultures would crash, and then we had to start all over again.

My curiosity of rotifer communities in different water bodies led to my carrying a plankton collection kit wherever I travelled. Even during my reluctant pilgrimages with my wife to sacred Himalayan shrines, I used to collect plankton samples from the high-altitude streams and lakes, much to the annoyance of my wife (Rotifers were extremely rare in those fast flowing and cold, oligotrophic waters). I used to leave preserved zooplankton collections often to students identify rotifers, cladocerans and copepods and keep records. But for live samples I was always ready. I remember the pleasure I used to derive from observing live zooplankton through a binocular microscope. That pleasure would double when we got a stereo zoom binocular with darkfield illumination. I would imagine the petri dish or the fingerbowl holding the sample to be a miniature ecosystem and watch the ongoing behaviours and interactions in it as a naturalist would in an African wildlife park. For me a *Polyarthra* darting away from an *Asplanchna* was no less fascinating than an antelope darting away from a cheetah.

Rotifer studies in my laboratory

Earlier taxonomic studies in India were mostly on preserved specimens collected from different water bodies, but when we entered the scene and started rotifers as our main research subjects, we wanted to do experimental ecology. Although HC Arora made some attempts to culture *P. patulus*, these were mostly fed on natural seston. We were arguably the first in the country to work with rotifers as *live* animals and conduct laboratory experiments on them using algae grown on defined medium. Over a period of many years, rotifers cultured in our lab were used either as the major experimental animals or as prey in predation experiments with copepods and fish larvae.

I had a research project in which we studied the feeding ecology of fish larvae or copepods. The larvae at hatching have a limited gape size which determines the size of the live food they could capture. In a study of prey size selection as a function of gape size we used rotifers of different sizes followed by cladocerans (*Moina*

and *Daphnia*). In that study we were also able to test some predictions of the optimal foraging theory.

Our earliest research using rotifers as experimental animals was an ecotoxicological study, in which we studied the effects of sublethal concentrations of DDT on survival and reproduction of a brachionid.

Sarma was persuaded to choose experimental ecology. His doctoral work was on the effects of predation (*Asplanchna*) and food (*Chlorella*) on the life table parameters of *Plationus patulus*, while Nandini's M Phil and Doctoral works were on Rotifer-Cladoceran-Cyanobacterial interact-ions.

Rotifers and cladocerans were used as prey by another student Ram Kumar in my lab in his doctoral work on predation in cyclopoid copepods. Unlike rotifers and cladocerans, culturing copepds and sustaining them is not easy, particularly since they are not parthenogenetic and therefore difficult to maintain in large numbers. With perseverance Ram Kumar completed his doctoral work on comparative experimental feeding ecology of calanoid and cyclopoid copepods. His current research interest is on microplastic pollution in rivers and its effects on freshwater food webs (Plate 2).

When the famous Belgian limnologist Herni Dumont visited India, I had an opportunity to discuss with him about the status of limnology in India. He appreciated the research going on in my laboratory and the way I trained my students. Dumont's laboratory in Ghent hosted two of my students (Sarma and Nandini).

International conferences:

Attending international conferences during my time was not easy since travel support was rarely available. I managed to attend only three Rotifer Conferences during my career: Spain (1991), USA (1997) and Thailand (2000). For all the three conferences the organizers (Maria Rosa Miracle, Elizabeth Wurdak and La-orsri Sanoamuang, respectively) had graciously offered me local hospitality and to them I remain grateful. I was to attend the Mexico Conference (2006), thanks to the generous travel support given by the organizers Sarma an Nandini, but unfortunately due to some last-minute airline ticketing mix-up I missed the conference. Bitter disappointment that was! Subsequently I did visit Mexico to impart biostatistics course using zooplankton as examples (see Rotifer News 36: 21, 2022). I still vividly remember my first Rotifer conference in Banyoles (1991) (Plate 3). What an excitement it was to meet for the first time celebrated Rotiferologists like Gilbert, Snell, Ricci, Miracle and above all, the granddaddy of rotiferologists, Walter Koste. Attending international conferences used to be like a fresh infusion of inspiration for me.

Painting has been my hobby for a long time. It was but natural that rotifers started demanding their representation and recognition in my art. I started incorporating rotifer motifs in Christmas-New Year Greeting cards

Plate 2. During active rotifer research. Left column: 1. Collecting plankton in an Arunachal Pradesh lake, 2. Plankton collections in Brazilian lakes; 3. Retirement function with students. Right column: 1 & 2. Plankton collecting in Taiwan, 3. During workshop in Mexico with participants.

Plate 2. Remembering Rotifera VI (Spain, 1991). Left: with Ramesh D Gulati and others. Right: With Sarma, P Starkweather and JJ Gilbert.

that I used paint in acrylics and send to rotiferologist friends. Later, digital era made it possible for me to create intricate '*mandala'* designs using rotifer images (Plates 4 and 5). A few examples of my artwork on rotifers previously appeared in Rotifer News too (see Rotifer News 35: 32, 2022).

Postretirement

I remained active after retirement in teaching, offering courses in Ecosystem Ecology, Environmental Studies and Basic biostatistics (I honed my online teaching skills during the COVID-lockout period).

Opportunities for remaining active in research are rarely available to researchers in India after retirement. Unfortunately, my research career had come to an end after retirement. Dreams of spending a short sabbatical with Gilbert or Snell while in service, and doing some collaborative project with Sarma-Nandini after retirement remained unrealized. I realize now with a tinge of sorrow and disappointment that I am no longer in the current Rotiferology scene where rotifers are finding their place in exciting new frontier fields like astrobiology, barcode taxonomy, anhydrobiosis and molecular evolution.

It has been many years since I had an opportunity of watching live plankton under a microscope, but rotifer images refuse to fade away from my memory. Although presently I spend my free time in reading, writing, and painting, vignettes of rotifers in action would periodically keep flashing in front of me, moving like Power Point slides in a presentation- a brachionid gracefully tumbling around like an inebriated ballerina, a male *Asplanchnopus* moving in a frenzy around its much larger and predatory mate, sneaking to impregnate it while trying to avoid becoming its dinner, *Hexarthra,* suddenly darting away like an athlete upon contact with *Asplanchna*, the ciliated corona of *Limnias* whirling like the *Sudarshan Chakra* of Hindu god Vishnu, and so

Plate 3. Artwork on different species of rotifers. Acrylic color painting of rotifers as they appear under darkfield illumination.

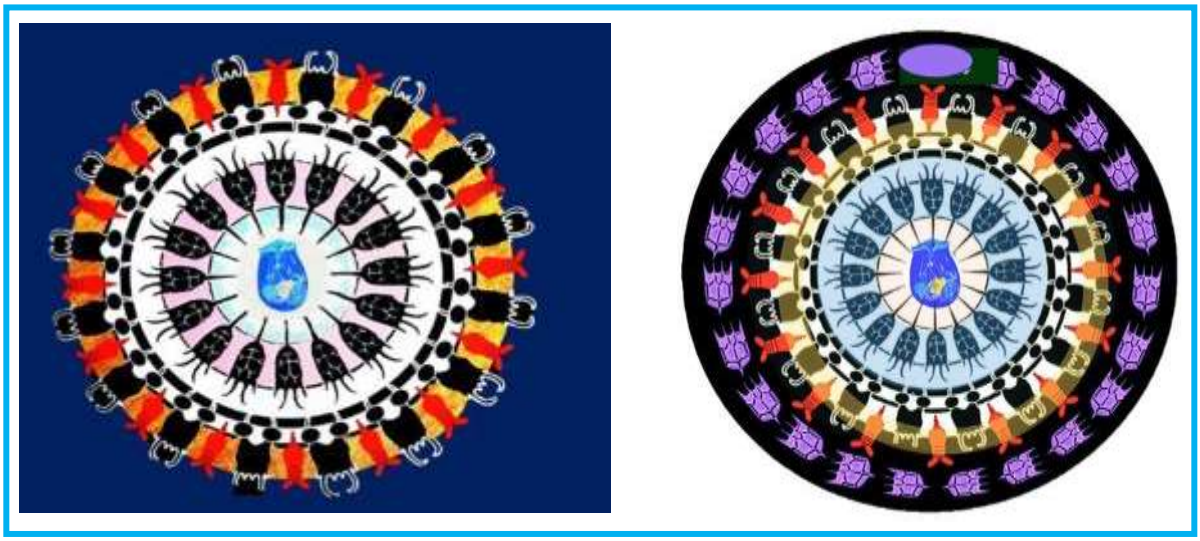

Plate 4. *Mandala* designs of Rotifer artwork. This pattern, *Rangooli*, is known for its symmetrical arrangement.

on. Some of my paintings still adorn the laboratory of Sarma and Nandini in Mexico!

Finally…

Periodically flipping through random pages in the book of my academic life, I would ask myself- "What has been my contribution to Rotiferology?". I am not known to be completely honest when it comes to self-assessment, so I cannot answer that question objectively. However, if you insist, I would say that my contribution to Rotiferology is perhaps my students like Sarma, Nandini and Ram Kumar, whom I had the privilege of mentoring during their formative years, and who are now widely recognized for the quality and relevance of their research. There is an ancient adage in Sanskrit- "*Sishyaat iccheth paraajayam".* Loosely translated, it means that a good teacher always wishes for his students to excel him in knowledge and skills. That's exactly what my students have done, and it gives me immense satisfaction and a feeling of fulfilment.

Notes and News

Updated information on IRS XVII

ROTIFER
XVII INTERNATIONAL SYMPOSIUM

Second Circular

The XVII International Rotifer Symposium will be held in the city of Rio de Janeiro, Brazil, from August 4th to 8th, 2025. The meeting will be hosted and organized by the Federal University of the State of Rio de Janeiro (UNIRIO) and supported by professors from the Federal University of Rio de Janeiro (UFRJ), the State University of Maringá (UEM), and universities from Argentina, Ecuador, Uruguay, and Venezuela. The theme of this congress will be "CHALLENGES FOR THE STUDY OF ROTIFERS IN THE SOUTHERN HEMISPHERE".

Logo

The logo and the visual identity of the symposium was created by the designer Beatriz Ramos (BSc). For the symposium's visual identity, the organizers chose to spotlight the rotifer species *Lecane decipiens* (Murray, 1913), which was described from samples collected in a small pond located in a square in downtown Rio de Janeiro city. The species is found in common bromeliad tanks typically found on UNIRIO campus. The arch below the *L. decipiens* corresponds to the southern Hemisphere.

Some illustrations representing the hills of Rio de Janeiro will also be used as logos for the meetings.

Venue

The XVII International Rotifer Symposium will be held at UNIRIO, which is located in Urca, a very charming area of the south part of the city of Rio de Janeiro. UNIRIO has two campuses in Urca. XVII IRS will be at the campus of Avenida Pasteur 296. Close to the UNIRIO area are several interesting places with wonderful views. These include the Earth Science Museum (400m walking distance from XVII IRS), Sugar Loaf cable car station (600m), Praia Vermelha (Red Beach), Claudio Coutinho Track (700m), Urca Wall (Mureta da Urca) (500 m), and the Rio Sul Shopping Center (450m), which has numerous shops and restaurants. We suggest these places for your visiting pleasure and for happy hours to reacquaint with old friends and to make new ones.

The auditorium Vera Janacópulos has a conference hall for 185 persons equipped for oral presentations, a lobby for refreshments and poster presentation, support rooms, ideal for events of all sizes, from small meetings to large conventions (*http://www.unirio.br/institucional/auditorios-anfiteatros-e-teatros*).

Registration Fee includes:
Access to ROTIFERA XVII main scientific program
Bag, congress materials and accreditation
Working lunch & refreshments
Mid-symposium excursion (Aug 06th)
Closing farewell meeting/party (Aug 08th)

Accompanying Persons Registration Fees include:
Bag and accreditation
Mid symposium excursion
Closing farewell meeting/party (Aug 08th)

Important dates
28th February, 2025 – Program Schedule
1st April, 2025 – Deadline for Abstract Submission

Registration fees

Category	Until March 15 Euro (€)	March 16 to May 31 Euro (€)	June 1 to July 15 Euro (€)
Regular	200	300	400
Student and accompanying person	100	150	200

Organizing Committee

Name	Institution	Country
Dr Adriana Puga	Universidade Federal do Estado do Rio de Janeiro	Brazil
Dr Betina Kozlowsky Suzuki	Universidade Federal do Estado do Rio de Janeiro	Brazil
Dr Christina Wyss Castelo Branco (President)	Universidade Federal do Estado do Rio de Janeiro	Brazil
Dr Roberto de Moraes Lima Silveira	Universidade Federal do Estado do Rio de Janeiro	Brazil
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Dr Viviane Bernardes	Universidade Federal do Estado do Rio de Janeiro	Brazil
Dr Clarice Casa Nova	Universidade Federal do Rio de Janeiro	Brazil
Dr Rafael Lacerda Macêdo	Freie Universität Berlin	Germany
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Organizing Committee (*continued*)

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UG Victor Luiz Mendez Jorge	Universidade Federal do Estado do Rio de Janeiro	Brazil

XVII International Rotifer Symposium
E-mail: rotifer2025@gmail.com
Instagram: rotifera2025
Website: https://rotiferxvii.com/

Recent literature

Related scientific publications

List of indexed works of Susana B. José de Paggi

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4. José de Paggi, S. 1976 Distribución espacial y temporal del zooplancton de un cuerpo de agua eutrófico (Lago del Parque Gral. Belgrano, Santa Fe). Physis B 91 (35): 171-183.

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For full-text articles, please consult the author

Susana José de Paggi
Email: **<sjdepaggi@gmail.com>**

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Miscellaneous

Generous donation of valuable literature from Prof. Brij Gopal

Prof. Brij Gopal, my beloved father and an avid reader, loved books. As a student, he used his food allowance to purchase subscriptions to literature and purchase books. As a result, his library grew in time. From one corner of our house to full room, to full house and then to entire basement, his library expanded to over 10 thousand books. Eventually he shifted his important collection to Peera Village (Chhatarpur District, Madhya Pradesh State, India) where he was working on developing a Centre for Inland Waters of South Asia. After his passing away, it took our family over 2 months to prepare catalogue of books so that they might be donated to institutes and universities. After two years of searching for a right place, Nalanda University emerged as best choice. The University was very positive about receiving this donation. They immediately responded to expedite the transfer and within three months, they collected and transported the book to the university.

The Gopal collection contains 6697 books including some rare and dating back to 1955. The collection includes Encyclopaedias, Journals, Science magazines, Newsletters, Proceedings of various National & International Conferences, Surveys of India, Reports of various Environmental Committees and Theses of Students.

Nalanda was World Renowned University historically where many great scholars from world-over came for higher education. It had world's richest library of which nine hundred thousand books or more were burnt down by Colonial rulers. Now, the University is being revived, re-established under Ministry of External Affairs, Government of India. Our Prime minister supports the University and Projects to re-establish Nalanda Library to help it reclaim its lost glory. Prof. Amartya Sen, Nobel Laureate Economist was first Vice Chancellor of Nalanda University. Prof. Brij Gopal's half century old enriching collection of Ecology and Environment reaching Nalanda University and Library has a huge significance.

To know more about this historical University, please click the website:

https://nalandauniv.edu.in/library/

https://nalandauniv.edu.in/about-nalanda/history-and-revival/

A few photos of late Brij Gopal from his Graduation Ceremony (Fig. 1), receiving Young Scientist Award from the former Prime Minister of India, Mrs. Indira Gandhi (Fig. 2), Lecture at Demystifying Aviralta & the e-flow Challenge (Fig. 3) and the last taken just before the Covid-19 outbreak in Feb. 2020 (Fig. 4).

Fig. 1 Graduation Ceremony of Prof. Brij Gopal (1962).

Fig. 2. First Recipient of the prestigious Young Scientist Award of the Indian National Science Academy, New Delhi (INSA), 1974.

Fig. 3. Demystifying Aviralta & the e-flow Challenge - Prof. Brij Gopal | IRW 2018.

Fig. 4. Prof. Brij Gopal in February 2020.

Given below are links to few articles written by colleagues and students as Tribute to Prof Brij Gopal.

https://nieindia.org/Journal/index.php/ijees/article/view/2467/656

https://www.downtoearth.org.in/water/brij-gopal-a-tireless-advocate-for-india-s-rivers-74974

https://link.springer.com/article/10.1007/s10750-024-05498-2

https://south-asia.wetlands.org/news/wetlands-international-south-asia-condoles-the-sad-demise-of-prof-brij-gopal/

Various lectures on Ecology, Rivers etc. are available on *youtube* and can be accessed freely from the web.

Sudha Gupta

Email: sudhabsg@yahoo.com

Mobile: +919810332713

Application of Shannon and Evenness Indexes to Publications on Rotifera: A Scientometrics Approach

S.S.S. Sarma

Universidad Nacional Autónoma de México (UNAM), Facultad de Estudios Superiores Iztacala (FES-I). Division of Research & Postgraduate Studies, Lab. of Aquatic Zoology, Av. de los Barrios No.1, Los Reyes Iztacala, Tlalnepantla, State of Mexico, Mexico- 54090.
Email: sarma@unam.mx

Abstract

Hirsch *h* index is one of the most widely used parameters to assess quantitatively the research output of an individual, an institution or a nation. Though some modifications of *h* index have been suggested, the use of other well-established indexes to complement this index has not been explored. Here I showed the use of Shannon index (*H'*) and Pielou's evenness (*J'*) for citation analysis. I selected rotifer workers with different *h* index values from Google Scholar and compared them with *H'*. This analysis showed positive curvilinear relationship between *h* and *H'*. Evenness *J'* in relation to *h* or *H'* initially increased with increasing index values, but thereafter plateaued. Using scientometric data, Shannon and Pielou indexes can be derived for classroom exercises in ecology.

Key words: Ecological indexes, citation analysis, *h* index, classroom teaching.

Introduction

Evaluation of research output by an individual, an institution or a nation is multi-dimensional. Some variables used to measure the research output include: 1. Total number of publications; 2. Frequency of publication; 3. Articles in journals from prestigious vs predatory publishers; 4. Journals with high impact factors and/or quartile ranking; 5. Number of authors per article, 6. First authors, corresponding author, etc.; 7. Readership / download rates, 8. Article type such as single page vs large reviews and Reference books; 9. Total citations to articles and/or books; 10. Positive vs negative citations; 11. Retracted articles; 12. Use of different types of indexes based on citations such as *h* index, *g* index, D-index, i_{10} etc. The use of any single method to quantify search contributions is 1993; Shah & Jawaid 2023). Yet, scientometric workers continue to generate valuable and quantitative indexes that are used by science administrators all over the world, especially for providing research funds, departmental promotions or national/ international awards (Zhang 2009).

Among the different quantitative indexes of articles based on citation counts, *h* index is highly popular (Hirsch 2005). This index deemphasizes citations for articles that are over- and under-cited. For a given researcher, the *h* index is defined as author with *h* number of articles, each of which has been cited at least *h* times. In simple terms if an author has 5 articles, each of these articles has been cited at least 5 times, then *h* = 5. At present *h* is widely available in different databases such as Web of Science (WoS), Scopus and

Google Scholar. The *h* index has some negative aspects too. For example, it overlooks highly cited works, which have enormous citations (> 1000) in literature, which are considered as significant contributions. Therefore, some alternative suggestions have been made, for example, *g*-index, which is based on Lotkaian theory (Egghe 2006). There are also some modifications of *h* index (e.g., h_m-index) giving importance to the order of authorships in multi-authored publications (Liu & Fang 2012). However, many of these modifications are largely restricted and their application to citation analysis and article rankings are not yet fully explored.

Research articles and their citations are also excellent material for application of other well-known indexes, such as Simpson (D) and Shannon diversity (*H'*) indexes, which are employed by ecologists. Author's articles and their citations satisfy assumptions of species diversity indices. For example, for using Shannon index, it is assumed that individuals of a species are randomly collected and all the species are represented in the sample (Konopiński 2020). For citations too, one can assume that different articles have been cited based on what is relevant, without prejudice.

Shannon (also known as Shannon-Wiener: Spellerberg & Fedor 2023) diversity (or entropy) index is particularly more suitable for the scientometric analysis because it was developed specifically based on information theory (Shannon 1948). This index is used in different fields of science, including architecture (Del & Tabrizi 2020) and economics, commerce and business (Straathof 2007). For deriving Shannon *H'* index two variables are needed: species richness and species abundances. For applying this to the citations, the number of articles published by an author in a particular research field is considered as equivalent to species richness. The citations received for each article is treated as equivalent to relative abundance of each species in a sample.

Scientometric works related to citation analysis are more concerned using *h* index or developing newer indices rather than application of already available quantitative information statistics. For example, even *h* index is essentially similar to the Eddington's *E* index developed for evaluating cyclists (Jeffers & Swanson 2005).

Using Shannon *H´* index for cited works has other advantages, for example, unlike *h* index, which is an integer (without decimals), Shannon index provides decimal level values that are useful to compare diversity of two or more ecosystems / citation data of two or more researchers. The decimal level accuracy is necessary even when the whole numbers are high. For example, Web of Science provides impact factor for journals up to three decimals even when the impact factor is higher than 100. Another important variable is the evenness (equitability, *J'*) which provides information on how evenly the abundances of different species are distributed in an ecosystem (Pielou 1975). In the scientometric analysis, this is equivalent to how many articles

of a given researcher have received similar number of citations.

The comparison of different indexes in citation analysis is common. Most comparisons have been made between *h* and modified *h* (Alonso et al. 2009). However, comparison of other indexes, particularly Shannon diversity *H′* with *h* index is not common. The use of *J′* in citation analysis is far less common.

Rotifers are an important group in zooplankton (Wallace et al. 2006). Since 1976, global rotiferologists meet every three years in different parts of the world to exchange ideas and/or data on this group of invertebrates (Wallace et al. 2013).

The aim of this analysis was to apply Shannon and evenness indexes to citation data and to compare with *h* index from selected works on Rotifera.

Methods

Basic citation data on rotifer citations was obtained from Google Scholar using the key words Rotifer, Rotifers, Rotatoria and Rotifera (data retrieved on 20 Nov. 2024). Selected rotifer workers with different *h* index values were randomly selected, representing a large range of cited articles, citations and *h* values. In all I chose 20 workers, whose publications in majority are on Rotifera. For each researcher three data sets were collected: Total number of articles, citation counts for each article and the corresponding *h* index.

For calculating Shannon index, the following formula was used (Krebs 1999):

$$H' = -\sum_{i=1}^{s} P_i - \ln P_i$$

Where, P_i is the proportion of individuals of the species *i*, *s* = species richness. For applying this equation to the citation analysis, P_i is the proportion of citations of the articles *i* (= number of citations of each article *i* / total number of citations), *s* = total number of cited articles of a given author.

For obtaining evenness, *J′*, the following equation was used (Pielou 1975):

$J' = H'/\ln S$

Where *H′* = Shannon diversity and *S* is the species richness (or total number of cited articles of a given author).

Results

I compared *h* index and Shannon index. Some differences and similarities between *h* index and Shannon *H´* index are presented in Table 1. Both these indices share some common features, which permitted to compare the selected data set used in this study. There was a positive relation between the total number of articles and the *h* index (Fig. 1A). However, when the total number of articles was plotted as function of Shannon index, the curve initially increased with increasing total cited articles up to 200 and thereafter it was stabilized (Fig. 1B). The relation between *h* index and Shannon *H′* index also showed initial increase of both these indexes but plateaued beyond *h* 50 and Shannon 5 (Fig. 2).

Evenness in relation to *h* index (Fig. 3A) or Shannon index (Fig. 3B) initially increased with increasing index values, but thereafter plateaued when *h* was about 30 or *H′* was about 3.

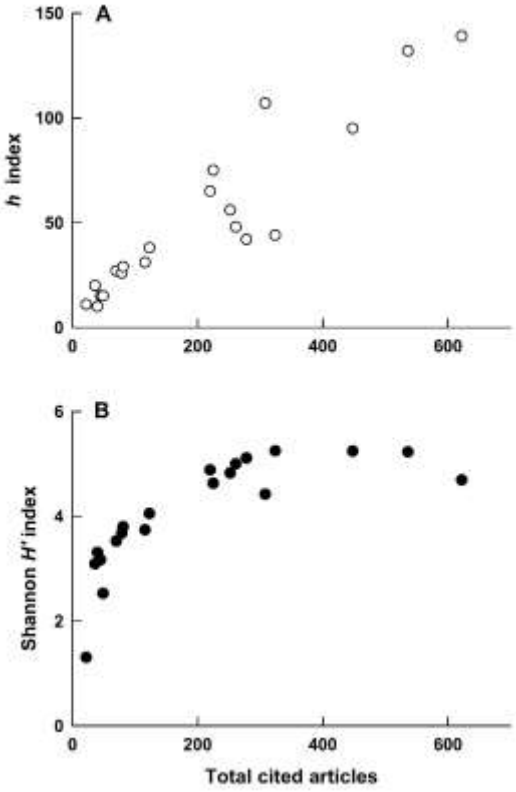

Fig. 1 Relationship between total number of cited articles vs Hirsch *h* index (A) and Shannon *H′* index (B) of 20 workers from the field of rotifer research. The data were obtained from Google Scholar.

Discussion

I found that the use of citation material for teaching students in understanding the behaviour of *H′* for diverse data sets is extremely helpful. This is because providing students with a very long list of species and their abundances is cumbersome for routine classroom exercises; this is particularly more tedious when different data sets are to be given to

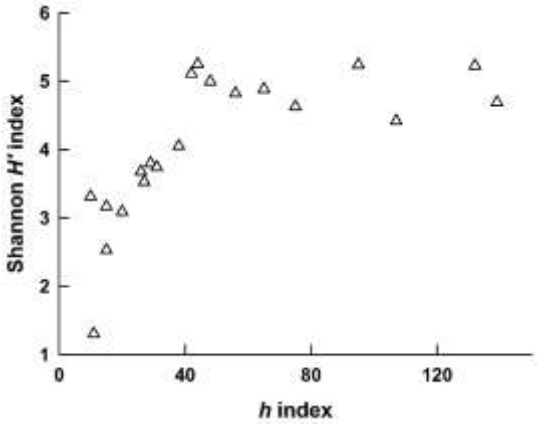

Fig. 2 Relationship between *h* index vs Shannon *H′* index of 20 workers from the field of rotifer research. Other details as in Fig. 1.

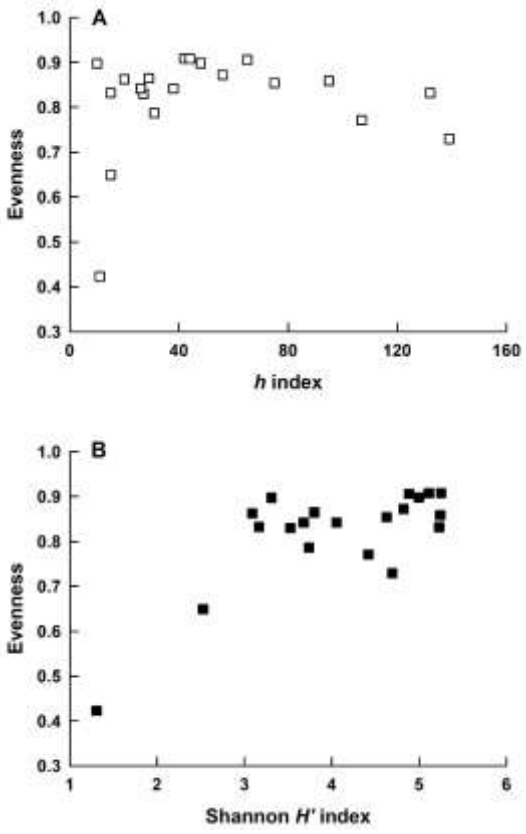

Fig. 3 Relationship between evenness and *h* index (A) and Shannon *H′* index (B) of 20 workers from the field of rotifer research. Other details as in Fig. 1.

Table 1 Some similarities and differences between *h* and Shannon *H'* index

Variable	*h* index	Shannon index
Differences		
Applicability / teaching	For citation analysis	Applicable for biology, engineering and economics
End product	integer	With decimal level values
Formula	one	Three formulas
Units	Only numbers	Bits/ind.
Equitability of citations	Does not consider evenness	Offers possibility to calculate evenness
Similarities		
Variables	Article number and its citations	Species number and its abundances
Articles without citations	Not considered	Species without abundances not considered
Software to calculate indexes	Available online	Available online
Modifications of original formula	Different alternatives available	Different alternatives available
Comparisons	Among researchers of a comparable field of science	Among comparable ecosystems / groups

different students with a long list of works. The enormous citation data are already and freely available from the web for classroom practice. More so, thanks to Google Scholar, several workers of a particular theme can be selected for applying Shannon index. Though quality data (e.g., journals with impact factor) are available in WoS or Scopus, these are subscription-based databases and therefore, for routine exercises, freely available web resources are adequate. Secondly, Google Scholar provides about 30% higher citation counts than any other internet search engines (Cabezas-Clavijo & Delgado-López-Cózar 2013; Ferreira et al. 2023). This provides higher data points for applying Shannon index and helps to compare *h* index.

I encountered certain limitations while searching citation data of rotifer workers. Many prominent rotiferologists have not yet registered with Google Scholar and hence their citation records are not available. The key words selected here do not faithfully retrieve the required data; some rotifer workers use other keywords such as plankton, limnology, zooplankton, etc. Therefore, I used here only representative workers or those known to have contributed to Rotifer science significantly. While processing data in Google Scholar, some citations with asterisk (*) needing verifications. These were not corrected because such instances are too few (<10). In addition, some rotifer workers, though have published predominantly on rotifers, have also authored data on other groups of organisms such as ciliates, Cladocera and Copepoda. Articles simultaneously containing data on rotifers with two or more groups of aquatic organisms were considered. Only author-verified databases are considered here because many authors in Google Scholar have similar names but with contributions in dissimilar fields of research; these are often wrongly indexed under the same author's name.

Shannon *H′* index can be calculated using $\log_{10}$, log natural (*ln*) or $\log_2$ for proportion of individuals of species richness, *i*. In this work, *ln* was used as it is common in literature. With $\log_2$ it produces binary digits or bits as the units. The higher the value of Shannon index, the higher is the species diversity. In citation analysis, this is comparable to *h*, where the higher the *h*, the higher is the prestige. When *ln* is used, the *H′* index rarely is >4 for ecosystems in nature. Therefore, getting higher than 4 in Shannon index for practice in the classroom is often difficult unless some hypothetical data are used. Fortunately, enormous citation data are available online for different researchers with a very wide range of total citations and *h* index. In the present study, I chose selected rotiferologists. However, when the rotifer researchers with high *h* value (<100) are not available in Google Scholar, I selected general zooplankton researchers, who have also contributed to rotifer research.

Hirsch index and Shannon index share some common features and these permit comparison for a given data set. For example, both these measures can quantify the research performance of a given author based on citation count. On a broader scale, *h* index is directly related to the total number of cited works. Thus, *h* index is a function of number of citable articles as well as their total citations (Hirsch 2005). Articles without citations are not considered either in *h* index or Shannon index. This does not imply that such works have no academic value. It simply shows that citation to articles is an important factor for quantitative assessment of research contributions.

The relation between cited articles vs *H′* index showed a curvilinear relation. It is necessary to include large data sets to confirm this trend. Ecologists have often shown *H′* index

for different ecosystems lies below 4 (Roswell et al. 2021). Using limited data on citations, I show here that it exceeds this number suggesting that larger data will provide a basis for confirming trends.

When using comparable data, Shannon index and Hirsch index show curvilinear relation. In this work, I did not attempt transformation of curves to obtain straight lines, but it is possible to derive a regression to predict the value of an index given the value of the other.

Evenness ranges from 0 to 1. When the relative abundances of species in an ecosystem are similar, evenness increases (Hubálek 2000). It is often an excluded parameter in citation studies. It is rare that for any given researcher the distribution of citations show perfect rectangular curve in relation to total works, implying that all published articles have the same number of citations.

Possibly one can expect close to *J′* = 1, especially when the number of published articles is low (e.g., <10). It appears that citations per article become uneven as the number of published works increases. The *h* index is not good predictor of this because it does not take into account of a large number of citations. Thus, two or more researchers have identical *h*, but with different total number citations or cited works. On the other hand, Shannon takes into account of all cited works and their citation count. From the Table 2, it is evident that both Shannon *H′* index and Pielou's evenness index *J′* provide quantitatively higher values, 12% and 2%, respectively, to the second researcher. It is however, necessary to test this using larger datasets.

Evenness decreases with uneven abundances of species. Higher evenness requires nearly similar relative abundances of different species. With large number of species in an ecosystem, it is more than likely that a few of them dominate while the rest may have fewer individuals. This asymmetric distribution of individuals contributes to lower evenness (Pielou 1966). In citations too, for any researcher, it is common that some articles are well cited over the others. This is independent of journal quality. For example, when the same author has two more works in the same journal on the related theme, some articles receive higher citations than the other. Thus, as in the case of

Table 2. Two researchers from an identical field of research within aquatic sciences were chosen from Google Scholar for comparing *h* index, Shannon index and Evenness index.

Author	Total cited articles	Total citations	*h* index	Shannon index	Evenness index
1	147	7119	44	4.098	0.821
2	243	6621	44	4.583	0.834

species richness in an ecosystem, in scientometrics too, with increase in the number of citable articles, there could be a decrease in symmetry in terms of number citations. This is evident in this analysis for Hirsch *h* and Shannon *H′* indexes. However, with larger data sets the trends may vary and this requires further testing.

The *h* index has also been used beyond authors' citation profiles. The *h* index is used for journals, for an institution or for a nation (Shah & Jawaid 2023). The use of Shannon index and evenness can also be extended for quantitative evaluation in these areas.

For applying Shannon index only two variables (number of species and their abundances) are considered. Other variables such as the value of indicator species are not considered. There are other indexes for this, for example, saprobic index (Pantle & Buck 1955). For this, the individual species saprobic value (or the valence) for each group of organisms is employed. For rotifers, the valencies developed by Sládeček are widely used. In the citation analysis too, the importance of journal impact factor or quartile rank is not considered. Therefore, *h* index may require modifications for including the journal impact factors or quartile rank.

In conclusion, this study shows that it is possible to use alternate indexes especially Shannon *H′* and Pielou *J′* for expressing quantitatively the research output in terms of number of articles and citations in a particular branch of science.

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Notes and News

Mexico-Türkiye Cooperation Research

Report on the International Training Program: *TÜBİTAK 2221 Guest or Sabbatical Scientist Support Program*

Within the scope of TÜBİTAK 2221 Guest or Sabbatical Scientist Support Program and invited from Mexico by Assoc. Prof Dr Meral Apaydın Yağcı to Bandırma Sheep Research Institute Directorate Fisheries Department, Prof Dr Singaraju Sri Subrahmanya Sarma and Prof Dr Sarma Nandini (National Autonomous University of Mexico) provided training on "Joint Project Writing" to the Fisheries Department Personnel between 09-20 December 2024. In this context, theoretical and practical studies on zooplankton identification, culture and ecology were carried out with staff and students of the Department of Fisheries and Chemistry.

Project Manager Dr Apaydın Yağcı gave the opening speech, introducing Fisheries Department and the Institute. Institute Briefing was presented by Elif Erbek Bozaba of our Institute. The field (Bandırma Sheep, Dog, Goose, Buffalo Breeding and Fisheries) and laboratories of other departments in the institute were introduced to guest scientists. A project writing activity on "Relationships of Cladocerans with toxic algae in freshwater ecosystems" was given by Dr Nandini. A project writing activity on "Toxicological test methods and application methods on Rotifera group zooplanktonic organisms in the freshwater ecosystem" was given by Dr Sarma (Photo 1).

The application area of the study was determined as Lake Manyas in Balıkesir Province. Prof Dr Yılmaz Arı from Bandırma Onyedi Eylül University gave an interesting presentation on "Lake Manyas: Cultural and Political Ecology of a Ramsar Site" for the introduction of Lake Manyas (Photo 2). In this way, Lake Manyas was introduced before going to the study area. We thank Prof Dr Yılmaz Arı for his contributions.

The invited guests and researchers of the Institute visited Manyas Lake and the Manyas Bird Paradise. The bird breeding areas were shown to

Photo 1. Presentations by Dr Nandini (left) and Dr Sarma (right).

Photo 2. Presentation by Dr Arı on the Lake Manyas

guest scientists and researchers live on video by officials of the National Park. In this context, we would like to thank the Bird Paradise National Park Directorate. Zooplankton samples were collected from Manyas Lake for species identification, ecotoxicological study and for culturing. A 55 µm pore-size plankton net was used to collect zooplanktonic organisms for species identification. In addition, a 10-liter lake water sample was filtered using scoop collector for the quantification of zooplankton (Photo 3).

In addition, 15 liters of water samples were brought from the Manda Drinking Water areas within the institutional area for culturing zooplankton. Filter paper was used to remove the suspended solids. Filtered lake water (100 ml) was used as medium to culture zooplankton. The filtered water was distributed into three separate clean beakers for culturing species of Copepoda, Cladocera and Rotifera from the samples. Species isolation was done using stereo microscope. The entire process was demonstrated to the Institute Fisheries Department staff by Dr Nandini. Then each researcher of the Institute also separated *Keratella cochlearis* and *Notholca squamula* using Pasteur pipette under stereomicroscope. Dr Nandini emphasized the importance of culturing *Notholca* species in Türkiye.

The identification and drawing of rotifer species from zooplankton samples from the Lake Manyas was shown to the participants of the Institute by Dr Sarma. For this, light microscopes fitted with photomicrographic camera were used. Researchers were given the opportunity to identify

Photo 3. Sampling study in Manyas Lake: left (MSc Abdulkadir Yağci); right (Dr Meral)

guides. Later, zooplankton counting process using Sedgwick Rafter the species using available keys and counting chamber used in counting zooplanktonic species was demonstrated to the researchers and the species were counted by the researchers. After the numerical densities of the species were determined, alpha diversity was calculated using Excel. In addition, trophic state index of lakes using data on species richness and abundances (individuals/L) of Rotifera were derived using different approaches (TSI_{Rot}, Total Rotifer Density and Saprobic index) (Photo 4).

from the medium and the daphniid was fixed. This process was repeated 3 times for 10 individuals. From the stock solution of a chosen toxin serial dilutions were made. The counting of the test individuals was done from each of the in 5 toxic concentrations after 1 day. The derivation of median lethal concentration (LC_{50}) was done using probit method. For this we used Sigma Pilot and Excel programmes. As part of this event, the institute infrastructure was shown to guest scientists, and the process of writing a joint Tubitak project with Mexico and Türkiye on these issues in the future has begun.

Photo 4. Laboratory Studies in Bandırma Fisheries Department

For ecotoxicological studies, *Daphnia* species was used as the test organism in the laboratory. After the isolation of *Daphnia* species, heart rate was quantified under a microscope and heart rate count was recorded by all participating researchers. The average heart rate was determined for 30 seconds. Then, 1 drop of toxin was added to *Daphnia* species under a stereomicroscope and waited for 1 minute. After 1 minute, toxin was withdrawn with a pipette and removed

At the end of the project writing activity, “Certificates of Appreciation” were presented to Dr Sarma and Dr Nandini by Assoc. Prof Dr Meral Apaydın Yağcı and by the Director of the Sheep Research Institute, Agricultural Engineer Koray Poyraz. Certificates of Participation were given to the researchers who participated in the training organized by Assoc. Prof Dr Meral Apaydın Yağcı and by the Deputy Director Haşim İnceoğlu (Photo 5).

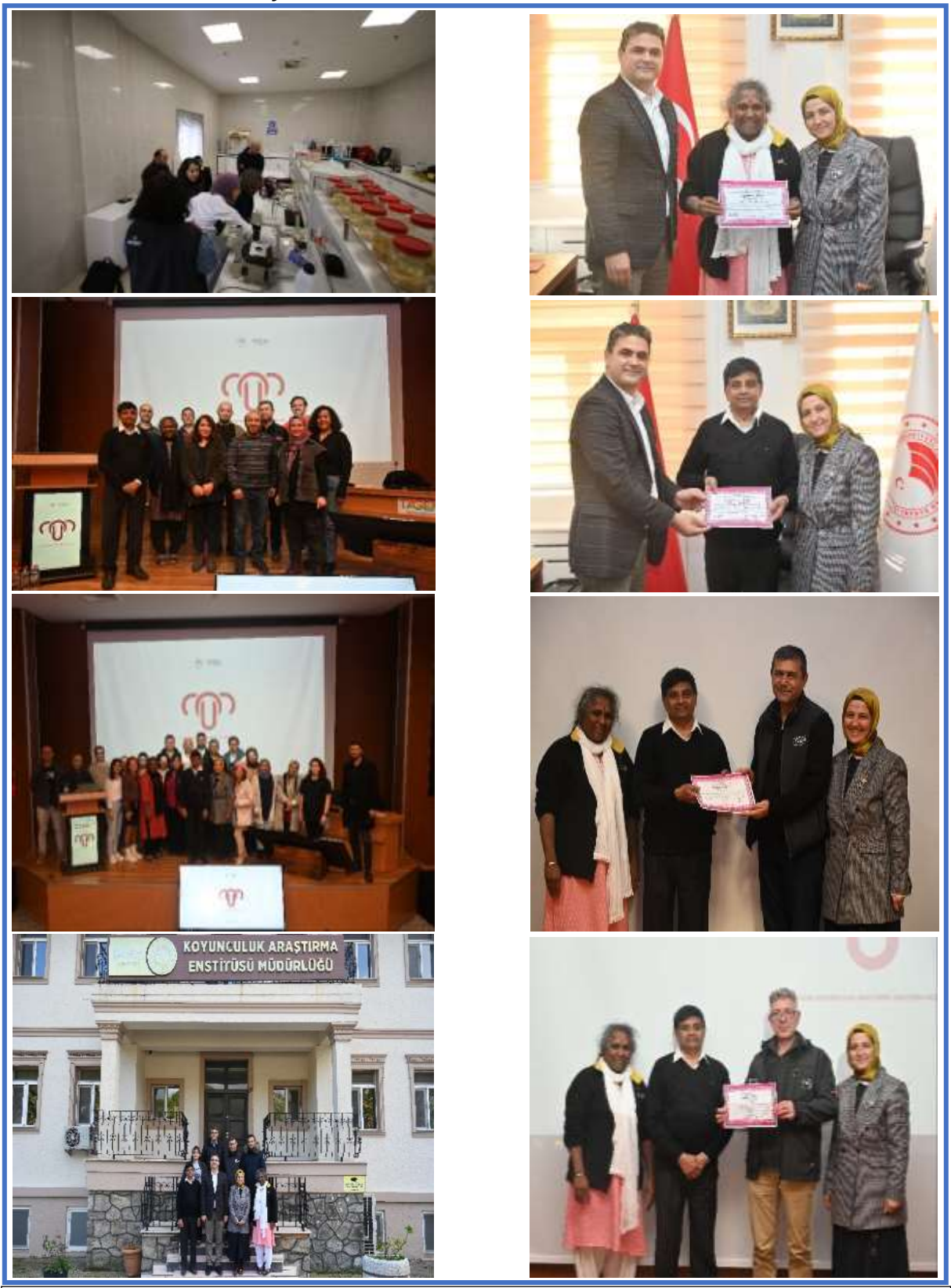

Photo 5. Left column: Course Participants and Administrative Staff of the Institute. Right: Presentation of Participation Certificates by the Institute Director; Organization Certificates to Dr Meral Apaydın Yağcı and MSc Abdulkadir Yağcı; Certificate of Institutional Support to the Deputy Administrative Director.

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Meral Apaydın Yağcı
Abdulkadir Yağcı

Republic of Türkiye Ministry of Agriculture and Forestry. Sheep Breeding Research Institute, Bandırma, Balıkesir, **Türkiye**

Emails:
meralyagci@gmail.com
meral.apaydinyagci@tarimorman.gov.tr

Authors are encouraged to submit contributions to *Rotifer News*.
Contact email account: **rotifernews@gmail.com**

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