ICES WGIMT REPORT 2017

SCICOM Steering Group on Ecosystem Processes and Dynamics

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Interim Report of the Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT)

31 March 2017

Boulogne-sur-Mer, France

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Conseil International pour l'Exploration de la Mer

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Executive summary

The ICES Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT) met on 31 March 2017, hosted by IFREMER in Boulogne-sur-Mer, France. During the meeting, WGIMT members reviewed progress on multi-annual ToRs, reports, and recommendations; evaluated progress and sought opportunities for partnerships in the ICES science and advisory communities.

WGIMT membership currently totals 47 members from 17 countries; new members were added again this year, continuing the steady increase in membership numbers each year since 2013. This trend is consistent with WGIMT goals to recruit and welcome new members (ToR a), in order to enhance our capacity for developing and using molecular and morphological approaches to taxonomic analysis of zooplankton.

Progress continued in the development and implementation of the WGIMT web platform for promotion and exchange of relevant scientific information (ToR b), with significant enhancements to website sections devoted to morphological, molecular, and optical approaches, including enhancements to a photo gallery of living zooplankton and a literature database.

WGIMT continued work to initiate and support provision of standards, preparation of training materials, and organization of formal workshops (ToR c). WGIMT members are named as expert instructors and/or organizers for two workshops in the coming year; several proposals for taxonomy workshops are pending. WGIMT promoted and encouraged the continuing integration of molecular and morphological taxonomy by organizing special sessions at national and international conferences, including the ICES 2017 Annual Science Conference and ASLO/TOS/AGU 2017 Ocean Sciences, among others (ToR d).

WGIMT is seeking avenues via the Ecosystem Processes and Dynamics Steering Group and other Science Committee Expert Groups to advise on implications and applications of integrative taxonomy for marine science and management (ToR e). During 2016/2017, WGIMT members published 13 peer-reviewed articles directly related to the core mission and goals of the EG (ToR f).

WGIMT is proposing recommendations for two new ToRs and is seeking cooperation with other EGs within the Ecosystem Processes and Dynamics Steering Group. WGIMT recommends a joint ToR with WGZE to determine the status of microzooplankton time-series data collection within the ICES area, assess progress made in this area over the last ten years, and identify collaboration, gaps or overlap with other WGs (WGIMT ToR g). WGIMT recommends a joint ToR with WGPME to review and evaluate methodologies used for metagenetic or metabarcoding analysis of plankton, with the specific goal of facilitating development of standardized protocols for applications in fisheries management and ecosystem assessment (WGIMT ToR h).

1 Administrative details

Working Group name

Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT)

Year of Appointment within current cycle

2017

Reporting year within current cycle (1, 2 or 3)

1

Chair(s)

Ann Bucklin, USA

Meeting venue

Boulogne-sur-Mer, France

Meeting dates

31 March 2017

2 Terms of Reference

ToR a) Ensure balanced morphological – molecular expertise among membership of WGIMT;

ToR b) Fully populate the WGIMT web platform with information, protocols and resources to support progress in research and development;

ToR c) Initiate and support provision of standards, training materials, and taxonomy workshops;

ToR d) Demonstrate leadership in promoting and encouraging use of integrative taxonomic approaches for assessment of pelagic biodiversity;

ToR e) Advise on the implications of developments for marine science and management;

ToR f) Publish high-profile peer-reviewed articles that provide documented evidence of advances in metagenetic analysis of zooplankton diversity, distribution, and abundance.

3 Summary of Work plan

ToR (a) WGIMT will continue to add new members, who are experts in morphological and molecular taxonomy for major zooplankton groups; 2 members in common with other SCICOM EGs (Years 1, 2, 3).

ToR (b) WGIMT will complete and fully populate all areas of WGIMT.net web portal (Year 1). Specially-designed elements and deep links will be completed to support and promote use of technologies (Years 1, 2). WGIMT.net web portal includes the following topics and sections:

- Morphological methods: Information and URL links to keys for morphological identification of zooplankton.
- Optical methods: Included in Morphological Methods section or updated.
- Molecular methods: A comprehensive summary of PCR and sequencing primers and protocols and associated references.
- Photo gallery: High-quality images of living zooplankton; photo galleries from the Census of Marine Zooplankton (www.cmarz.org) migrated.

ToR (c) WGIMT will design, organize and offer integrative taxonomy workshops, including requesting support via ICES Taxonomy Workshop funds (Year 2).

ToR (d) Organize special sessions at national and international conferences, including ASLO/AGU Ocean Sciences Meetings and the ICES Annual Science Conferences, among others. (Years 1, 2, 3).

ToR (e) WGIMT will report via SSGEPD and SCICOM EGs on the promise, progress and pitfalls of integrative morphological – molecular taxonomy and metagenetics or metabarcoding (i.e., high throughput sequencing of environmental samples) for integrated ecosystem assessments (Years 2, 3).

ToR (f) WGIMT members will publish at least two papers each year focused on integrative taxonomy of zooplankton, using state-of-the-art molecular approaches, including overview, review, and perspective articles (Years 1, 2, 3).

4 List of Outcomes and Achievements of the WG in this delivery period

Relevant Publications by WGIMT members

Aarbakke, O.N.S., S.-E. Fevolden, A. Weydmann (2017) Relative summer abundances and distribution of Pseudocalanus spp. (Copepoda: Calanoida) adults in relation to environmental variables in the Nordic Seas and Svalbard fjords. Polar Biol 40: 51–59. DOI 10.1007/s00300-016-1923-0

Abad, D., A. Albaina, M. Aguirre, A. Laza-Martínez, I. Uriarte, A. Iriarte, F. Villate, A. Estonba (2016) Is metabarcoding suitable for estuarine plankton monitoring? A comparative study with microscopy. Mar Biol 163: 149 DOI 10.1007/s00227-016-2920-0

Aylagas, E., Á. Borja, X. Irigoien, N. Rodríguez-Ezpeleta (2016) Benchmarking DNA metabarcoding for biodiversity-based monitoring and assessment. Front. Mar. Sci. 3: 96. doi: 10.3389/fmars.2016.00096

Brylinski, J.-M., L.-L. Li, L. Vansteenbrugge, E. Antajan, S. Hoffman, K. Van Ginderdeuren, D. Vincent (2016) Did the Indo-Pacific leptomedusa *Lovenella assimilis* (Browne, 1905) or *Eucheilota menoni* Kramp, 1959 invade northern European marine waters? Morphological and genetic approaches. Aquatic Invasions 11: 21–32

Castellani, C., M. Edwards [Eds.] (2016) Marine Plankton: A Practical Guide to Ecology, Methodology, and Taxonomy. Oxford University Press.

Cornils, A., B. Wend-Heckmann, C. Held (2017) Global phylogeography of *Oithona similis* s.l. (Crustacea, Copepoda, Oithonidae) – A cosmopolitan plankton species or a complex of cryptic lineages? Molec Phylog Evol 107: 473–485

Danovaro, R., L. Carugati, M. Berzano, A.E. Cahill, G.S. Carvalho, A. Chenuil, *et al.*, A. Borja (2016) Implementing and innovating marine monitoring approaches for assessing marine environmental status. Front. Mar. Sci. 3: 213. doi: 10.3389/fmars.2016.00213

Peralba, À., M.G. Mazzocchi, R.P. Harris (2016) Niche separation and reproduction of *Clausocalanus* species (Copepoda, Calanoida) in the Atlantic Ocean. Prog. Oceanogr. http://dx.doi.org/10.1016/j.pocean.2016.08.002

Questel, J.M., L. Blanco-Bercial, R.R. Hopcroft, A. Bucklin (2016) Phylogeography and connectivity of the *Pseudocalanus* (Copepoda: Calanoida) species complex in the eastern North Pacific and the Pacific Arctic Region J. Plankton Res. 38: 610–623.

Weydmann, A., N.C. Coelho, E.A. Serrão, A. Burzynski, G.A. Pearson (2016) Pan-Arctic population of the keystone copepod *Calanus glacialis*. Polar Biol 39 :2311–2318. DOI 10.1007/s00300-016-1898-x

Theme Sessions and Workshops Organized by WGIMT Members

WGIMT, WGZE and WGPME co-sponsored a Theme Session at the ICES 2017 Annual Science Conference (Fort Lauderdale, Florida, USA), *Microbes to Mammals: Metabarcoding of the Marine Pelagic Assemblage*, co-convened by Ann Bucklin (USA), Rowena Stern (UK), Katja Metfies (Germany).

WGIMT member Rowena Stern (UK) is an organizer of an international workshop, organized in partnership with WGPME, *Symposium on High Throughput Methods Applied to Marine Biodiversity Time Series* to be held during October 11-13, 2017 in Hannover, Germany.

WGIMT members Ann Bucklin (USA) and Leocadio Blanco-Bercial (Bermuda) will convene a session, *Rediscovering Marine Biodiversity: Progress, Promise, and Challenges of Metabarcoding of Microbes to Mammals*, at the 2018 Ocean Sciences Meeting (Portland, Oregon, USA; February 10-16, 2018).

5 Progress report on ToRs and workplan

ToR (a) Ensure balanced morphological – molecular expertise among membership of WGIMT

The WGIMT membership has grown consistently each year since the creation of SGIMT in 2012. WGIMT membership now totals (as of 31 March 2017) 47 members from 17 countries (Figure 1). There are members in common with WGZE, WPME, WGAGFM, WGBOSV and WGITMO. A total of 17 members and guests attended WGIMT 2017 Annual Meeting in person. WGIMT has now largely met the goals of this ToR for expanded membership. New members are still welcome, especially those who develop and use molecular and/or morphological approaches to taxonomic analysis of zooplankton. Membership in WGIMT extends to scientists working in any ocean region, in addition to the ICES region.

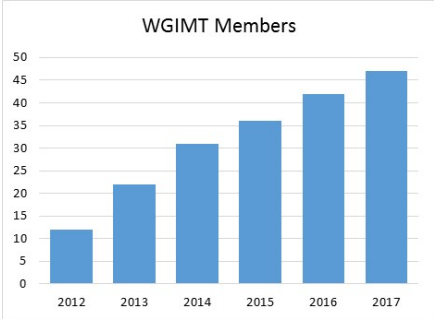


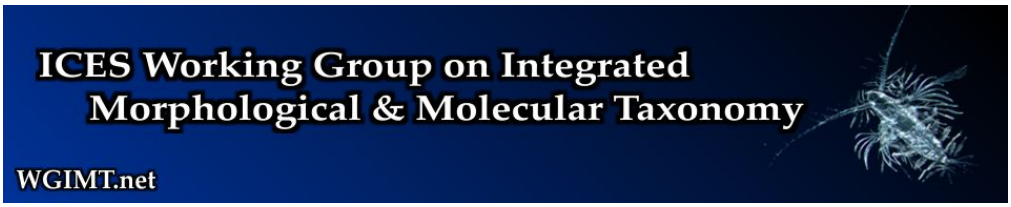
Figure 1. Numbers of WGIMT members each year 2012–2017.

ToR (b) Fully populate the WGIMT web platform with information, protocols and resources to support progress in research and development (Years 1, 2, 3)

a) Locating and accessing morphological and molecular taxonomic information can be difficult: some classical taxonomic references are out-of-print; molecular data are not released prior to publication.

b, c) Open access to data and information will expand use of state-of-the-art molecular technologies (e.g., High-Throughput Sequencing) for integrative taxonomy of zooplankton. Complete and fully populate all areas of WGIMT.net web portal (Year 1). Complete specially-designed elements and deep links to support and promote use of technologies (Years 1, 2).

The WGIMT.net web portal has been expanded and updated throughout the three years. In addition to providing general information about WGIMT, the portal comprises two major topic areas:



The *Morphological Methods* topic area includes:

- Overview: This section is a brief introduction to the topics and issues of morphological species identification.
- Identification Keys: This section provides a collection of web links (if online media) and literature references (if published media) for zooplankton taxonomic keys and identification resources. This section spotlights the ICES *Identification Sheets for Zooplankton*, which are being updated and refreshed by WGIMT/WGZE in an effort expected to continue over the next few years (see description for ToR c, below).
- Photo Gallery: This section features over 275 photographs of plankton migrated from the Census of Marine Zooplankton (CMarZ) project and/or contributed by WGZE and WGPME members (Figure 2). The photos are stored in "COPEPEDIA, http://copepedia.org/", a relational taxonomic database collaboratively developed by COPEPOD / WGIMT / WGZE / WGPME. The photos

are each stored under their associated taxonomic name, along with observational distribution maps and any available primer, biometric, and size/biomass information for that taxa (COPEPEDIA represents the effort and output from multiple ToRs in the WGIMT, WGZE, and WGPME working groups.)

Figure 2. Selected images from the WGIMT.net photo gallery.

- Optical Methods: This section gives an overview of optical methods for plankton identification. It provides examples of eleven different optical sampling instruments, including photographs of each instrument as well as literature and web links for more information.

The *Molecular Methods* topic area includes:

- Overview: This section is a brief introduction to the topics and issues of genetic and metagenetic analysis of zooplankton.
- Primers & Protocols: This section gives access to a database of over 100 PCR and sequencing primers (see Table 1). The data elements can be accessed alltogether in a single spread sheet, or they can be accessed via their associated taxa entries in COPEPEDIA (as mentioned in the Photo Gallery section above).
- Literature: This section contains a listing of over 40 publications providing protocols, methods, and sequencing primer references.

Table 1. Excerpted section of the WGIMT.net primers and protocols table.

GENE	TAXON	PRIMER		PRIMER SEQUENCE	REFERENCE
MtCOI	Copepods	Cop-COI-2105R	R	CGRTCHGTHARNARYATDGTAATDGC	Bucklin et al. 2010a
MtCOI	Copepods	Crus-COI-2198R	R	CCHACDGTAAAYATRTGRTG	Bucklin et al. 2010a
MtCOI	Copepods	Crus-COI-2428R	R	TTAATHCCHGTDGGNACVGCAAT	Bucklin et al. 2010a
MtCOI	Copepods	HCO-Co-2358	R	CCHACDGTAAAYATRTGRTG	Bucklin et al. 2010b
MtCOI	Calanoida	LCO-1703	F	CTATTTGATTGGAGGATTTGG	Hill et al. 2001
MtCOI	Calanoida	LCO-1719	F	GGATTTGGTAACTGATTAGTGCC	Hill et al. 2001
MtCOI	Calanoida	H2612-COI	R	AGGCCTAGGAAATGTATAGGGAAA	Figueroa 2011
MtCOI	Calanoida	L592-RCOI	F	AACCTTAATACATCTTTTTATGATG	Figueroa 2011
MtCOI	*C. helgolandicus*	ChelgCOI-F	F	GGCCAAAACAGGGAGAGATA	Papadopoulos et al. 2005
MtCOI	*C. helgolandicus*	ChelgCOI-R	R	CGGGACTCAGTATAATTATTCGTCTA	Papadopoulos et al. 2005

ToR (c) Initiate and support provision of standards, training materials, and taxonomy workshops

ICES Plankton Leaflets

Antonina dos Santos reported on the update and the revision of the ICES Plankton Leaflets with an overview over the new leaflets structure and content. She mentioned that the leaflets will be hosted at the WGZE website, while the copyright remains at ICES. Lidia Yebra commented that a few years ago it was possible to have the leaflets as a repository on your institute's page.

Elvire Antajan asked whether it would be of interest to include pictures taken by new imaging tools into the leaflets, although what can be depicted by new image systems might be limited in taxonomic resolution (e.g., the genus, but not species, may be identified, as for the copepod *Acartia*). Antonina replied that the aim of the leaflets would be a provision of keys for species identification, although she and her co-editor Claudia Castellani may decide to add links to pictures taken by optical systems in some leaflets. Peter Wiebe and Todd O'Brien asked about the option to have the leaflets in more than one file format (e.g., PDF, HTML). Also planned for inclusion in the leaflets are links to molecular information, which will be accomplished through collaboration with Naiara Rodríguez-Ezpeleta.

Antonina explained that the leaflets differ in the taxonomic levels profiled, which depends on the particular group. Maria-Grazia Mazocchi asked whether a working plan could be distributed to EG members, including a list of species that have been updated. This did not seem to be feasible at this time, so a request was made to WG members to provide information on experts that could be contacted for assistance in updating any of the leaflets. Ann Bucklin confirmed that any new information on the leaflets would in time be shared with WG members as it became available.

Taxonomy Workshop Proposals and Planning Suggestions

Workshops, including ICES Taxonomy Workshops, are very effective in engaging target audiences and ensuring trained technicians and researchers for applications in fisheries. After an introduction by Maria Grazia Mazzocchi on this topic, a discussion followed on the possibility of running a practical workshop dedicated to taxonomy, on both a morphological and molecular level according to the needs of the WGZE and WGIMT. The advanced course on taxonomy of phytoplankton in Naples which also includes molecular approaches was given as an example.

WGIMT is supporting and co-sponsoring a proposal for an advanced international training course, *Integrative Morphological and Molecular Taxonomy of Marine Planktonic Copepods*, proposed to be held at the Stazione Zoologica Anton Dorhn (SZN, Naples, Italy) during September, 2018. Maria Grazia provided an overview of the course contents. As discussed previously, financial support for the workshop is proving to be very challenging. Earlier workshops (e.g., the phytoplankton workshops) were funded by EuroMarine and other organizations, which are no longer providing funding for these activities.

Peter Wiebe mentioned that the last SAHFOS zooplankton workshop in 2016 was overbooked, although not everybody was offered funding to participate. Lidia added that the SAHFOS workshop was very expensive. Ann Bucklin added that SAHFOS offered funding for about 15 students for the zooplankton taxonomy workshop in 2016, although the 2017 phytoplankton workshop was not funded.

Elvire Antajan mentioned that the French network of marine monitoring stations has possibility to organize workshops including funding. However, she did not know whether people outside of France could organize those workshops, but they could definitely attend and people could be invited to give lectures. Antonina mentioned that it would be important to have a workshop with both students and advanced scientists. Piotr Margonski asked about the availability of microscopes, and Elvire answered that universities are often able to provide microscopes. Maria Grazia added that SZN also has enough microscopes available to be used for these types of courses.

Regarding funding for ICES workshops, Piotr Margonski added that ICES continues to be interested in supporting taxonomy workshops, although participants must pay the full costs and the workshops usually take place in Copenhagen. Antonina dos Santos summarized upcoming ICES training courses: for 2017, eight training courses are being organized, with seven of them to be held in Copenhagen (DK) and the eighth in Bergen (NO). ICES also strongly promotes and sponsors online training.

After more discussion about the very limited funding availability, it was decided that the deliverables of this ToR needed to be adapted to the current situation, with realistic assessment of funding. Also WGIMT should report upon the involvement of EG members in workshops that support the goals of this ToR. Among these are:

- A symposium on *High Throughput Methods in Marine Time Series*, to be held near Hannover, Germany on October 11-13, 2017. The workshop is primarily a product of ICES WGPME, but WGIMT members are among the meeting organizers, e.g., Rowena Stern (UK), and several WGIMT members are invited participants, including Ann Bucklin (USA).
- An advanced international training course on *Integrative Morphological and Molecular Taxonomy of Marine Planktonic Copepods*, proposed to be held over two weeks during September 2018 at Stazione Zoologica Anton Dorhn (SZN, Naples, Italy). Several WGIMT members will be invited instructors. Among the scientific coordinators for the course is WGIMT member Maria Grazia Mazzocchi (Italy).
- A workshop for experts working on the calanoid copepod *Pseudodiaptomus marinus* in European waters is planned for October – November, 2017 at the Stazione Zoologica Anton Dohrn (SZN, Naples, Italy). The goal of the work-

shop is to foster the creation of an expert working group on the topic. Among the organizers is WGIMT member Maria Grazia Mazzocchi (Italy).

ToR (d) Organize special sessions at national and international conferences, including Ocean Sciences Meetings, ICES Annual Science Conference, others

WGIMT members have taken the lead in organizing special sessions at national and international conferences each year, including: ASLO/AGU/TOS Ocean Sciences Meetings, ICES Annual Science Conference, among others.

WGIMT, WGZE and WGPME co-sponsored a Theme Session at the ICES 2017 Annual Science Conference (Fort Lauderdale, Florida, USA), *Microbes to Mammals: Metabarcoding of the Marine Pelagic Assemblage*, co-convened by Ann Bucklin (USA), Rowena Stern (UK), Katja Metfies (Germany).

WGIMT is participating in an international meeting, *Symposium on High Throughput Methods Applied to Marine Biodiversity Time Series* to be held during October 11-13, 2017 in Hannover, Germany. The workshop will focus on molecular techniques, imaging and flow cytometry-based techniques, networking tools and science communication, and seeks to produce a roadmap for future research and training.

WGIMT members will convene a session, *Rediscovering Marine Biodiversity: Progress, Promise, and Challenges of Metabarcoding of Microbes to Mammals*, at the 2018 Ocean Sciences Meeting (Portland, Oregon, USA; February 10-16, 2018).

WGIMT, in partnership with WGZE, submitted a Theme Session proposal for the ICES 2018 ASC, *Molecules and Morphology: Integrative Taxonomic Analysis of Marine Plank-Tonic Assemblages* (Annex 5), with WGIMT/WGZE member co-conveners, Pennie Lindeque (UK), Lidia Yebra (ES), and Ann Bucklin (USA).

ToR (e) Advise on the implications of developments for marine science and management

This ToR has two related, but somewhat distinct, goals focused on providing new molecular tools for integrated ecosystem assessments. First, WGIMT seeks to promote and facilitate the use of integrative morphological – molecular taxonomy as a foundation for assessing species, diversity and abundance of marine organisms, especially zooplankton, in integrated ecosystem assessments. Second, WGIMT is actively engaged in efforts leading to standardization of metagenetic and metabarcoding approaches to fulfil requirements of biodiversity assessments and indicators defined in the Marine Strategy Framework Directive (MSFD). WGIMT proposes to collaborate with WGPME, WGAGFM, and other EGs, especially in SSGEPD and SCICOM, to report upon the promise, progress and pitfalls of metagenetics or metabarcoding.

Metagenetic analysis (also called metabarcoding) is revolutionizing the analysis of marine biodiversity due to the promise of rapid detection and description of the impacts of climate change on marine ecosystems. Standardization and validation of metabarcoding analytical approaches is necessary for development of practical indicators and useful applications for assessment and management of pelagic ecosystems, including calculation of biotic indices, targeted detection of indicator species, food-web analysis, and detection of introduced, non-indigenous species.

In response to a request from SCICOM via SSGEPD (in April 2017) for new products or viewpoints (i.e., topics that advice has not been previously requested by a client), WGIMT submitted a proposal for development of standardized biodiversity indices based on molecular (metagenetic or metabarcoding) analysis, to be used for assessment, management, and monitoring of pelagic ecosystems, including targeted contributions for quantifying the effects of climate change and evaluating the role of structural and functional diversity in marine ecosystems, consistent with the Marine Strategy Framework Directive [MSFD, see ToR (e), Deliverable c]. A product focused closely on the biodiversity of the zooplankton assemblage would be possible with collaboration between WGIMT and WGZE; the more comprehensive goal of examining biodiversity of the pelagic ecosystem would require collaboration and cooperation with other ICES SCICOM and ACOM EGs.

Discussion during the WGIMT meeting focused on additional WGIMT activities in support of ICES scientific and advisory goals and priorities. The suggestion was made small groups of WGIMT members might be created for these topic areas to consider appropriate and possible options and approaches for WG contributions. Topics mentioned include:

- Detection of non-indigenous species (NIS) in ballast water: Activities might include baseline port surveys, which can be used to grant exemptions, and other priorities related to meeting ICES goals for ballast water treatment systems.
- Analysis of trophic relationships and food web dynamics: Metagenetic (metabarcoding) approaches are being widely used for analysis of the diets and prey preferences of commercial fish species, including herring, anchovy, and sardine. The molecular results are being compared to traditional microscopic examination, in order to evaluate and interpret the different types of information molecular approaches can provide. Related research is using quantitative PCR (qPCR) approaches for quantification and evaluation of relative importance of prey types.
- Metagenetic analysis of biodiversity: WGIMT members are actively working to evaluate the impact of using different gene markers for metabarcoding analysis of pelagic biodiversity. These are also being compared with results from the morphological taxonomic analysis of samples, especially for mock communities and test samples with identified species and quantification of species abundance (counts) and/or biomass. An example of progress toward development of standardized biotic indices for use in management and assessment was described and referenced (Aylagas *et al.*, 2014, 2016).
- Identification of knowledge gaps and research needs: WGIMT can and should provide useful leadership in identifying topics and areas of high priority for new research and application of integrative morphological - molecular taxonomic approaches. WGIMT should focus in particular on the need for integration and identify opportunities for morphological taxonomists and geneticists to work together. These include: 1) impacts of gene marker of choice for identification of taxa; and 2) gap analysis to evaluate taxonomic constituents in reference databases.
- Reference DNA sequence databases for target species, groups, and regions: WGIMT should consider development of proposals to support creation of

comprehensive reference databases to support identification of taxa (Operational Taxonomic Units, or OTUs) resulting from metabarcoding analysis. Consideration should be given to coordination and collaboration with the Barcode of Life Database (BOLD, see URL http://www.boldsystems.org/); Ocean Genome Legacy (see https://www.northeastern.edu/ogl/); and others.

ToR (f) Publish high-profile peer-reviewed articles that provide documented evidence of advances in metagenetic analysis of zooplankton diversity, distribution, and abundance.

Lidia Yebra presented an overview about the published peer-reviewed articles (see list in Section 4, above). Related to ToR (e), three publications focused on the advancement on metagenetic / metabarcoding methods and/or compared methods suitable for monitoring and integrated ecosystem assessment. Another six publications represent integrative studies addressing phylogeography and connectivity using morphological and barcoding techniques. Finally, the book, *Marine Plankton: A Practical Guide to Ecology, Methodology, and Taxonomy*, co-edited by WGIMT member Claudia Castellani was published (Figure 3). Information on molecular approaches is included in this book. Several members of the group contributed to various chapters.

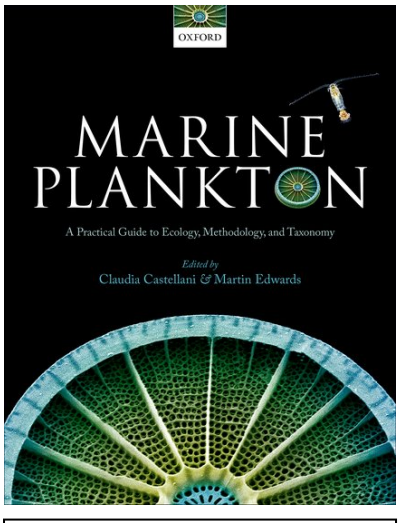


Figure 3. Marine Plankton (2017) co-edited by Claudia Castellani (UK).

Elvire Antajan suggested adding to the list a publication on Hydrozoa using an integrative approach. Naiara Rodriguez-Espeleta asked whether future work will also include protists. Since this might led to large overlap with WGPME, the group decision was to focus only on multicellular organisms. Jasmin Renz suggested presenting the publications and the groups work separately in two major topics following the distinction of methodological progress in molecular methods and of integrative publications presented by Lidia Yebra. Because these covers the two main foci of the WGIMT, the suggestion was positively received by the group.

6 Revisions to the work plan and justification

WGIMT is recommending a new ToR to be carried out in collaboration with WGZE. WGIMT ToR (g): *Determine the status of microzooplankton time-series data collection within the ICES area*. This effort builds upon previous WGZE efforts, including a 2007 review of the role of microzooplankton in the marine food web, which called for inclusion of both micro-and mesozooplankton experts in the EG, and encouraged microzoplankton time-series sampling and monitoring within the ICES area. This new ToR will assess progress made in this area over the last ten years and strengthen collaboration of WGIMT with WGZE and other EGs. Science Plan topics addressed: 1.3.1, 4.1.1 & 4.2.1. Products will include lists of scientists and laboratories measuring microzooplankton groups within time-series datasets; data table to compare sampling & analysis methods and to indicate which groups are regularly counted and which groups are routinely being missed; database input; and webpage content update.

WGIMT is recommending a new ToR to be carried out in collaboration with WGPME. WGIMT ToR (h): *Review and evaluate methodologies used for metagenetic or metabarcoding analysis of plankton*, with the specific goal of facilitating development of standardized protocols for applications in fisheries management and ecosystem assessment.

7 Next meetings

WGIMT has elected new co-chairs Naiara Rodriguez-Ezpeleta (ES) and Elaine Fileman (UK) to serve for 2018-2019.

During Year 2 (2018), WGIMT proposes to meet in association with the Working Group on Zooplankton Ecology (WGZE) during 19-23 March 2018 in Helsinki, Finland, with a dedicated WGIMT meeting on 23 March 2018, hosted by Maiju Lehtiniemi (SYKE). Additional work will be carried out by correspondence and videoconferencing.

Annex 1: List of participants

Member	Dept/Institute	Email	Attend 2017
Agata Weydmann	University of Gdansk	agataw@ug.edu.pl	Yes
Aitor Albaina Vivanco	University of the Basque Country (del Pais Vasco)	aitoralbaina@hotmail.com	No
Amy Maas	Bermuda Institute of Ocean Sciences	amy.maas@bios.edu	No
Andone Estonba Rekalde	University of the Basque Country (del Pais Vasco)	andone.estonba@ehu.es	No
Ann Bucklin	University of Connecticut	ann.bucklin@uconn.edu	Yes
Antonina Santos	Portuguese Institute for the Sea and the Atmosphere (IPMA)	antonina@ipma.pt	Yes
Astrid Cornils	Alfred-Wegener-Institute Foundation for Polar and Marine Research	Astrid.Cornils@awi.de	No
Astthor Gislason	Marine Research Institute	astthor@hafro.is	Yes
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Annex 2: Recommendations

RECOMMENDATION	ADRESSED TO
1. 3. WGIMT is recommending the appointment of new EG co-chairs Naiara Rodriguez-Ezpeleta (ES) and Elaine Fileman (UK), who were elected during the 2017 WGIMT meeting to serve for 2018-2019, the remaining of the approved WGIMT MA 2017-2019 term.	SCICOM
2. WGIMT recommends that the 2018 meeting be held on 24 March 2018 in Helsinki, Finland. WGIMT proposes to meet in association with WGZE, which is scheduled for 19-23 March 2018.	SCICOM
3. WGIMT recommends a joint ToR with WGZE to determine the status of microzooplankton time-series data collection within the ICES area, assess progress made in this area over the last ten years, and identify collaboration, gaps or overlap with other WGs. [WGIMT ToR (g)]	WGZE
3. WGIMT recommends a joint ToR with WGPME for review and evaluation of methodologies used for metagenetic analysis of plankton, with the specific goal of facilitating development of standardized protocols for applications in fisheries management and ecosystem assessment. [WGIMT ToR (h)]	WGPME
4. With WGZE, WGIMT is proposing a Theme Session for the ICES 2018 Annual Science Conference entitled, "Molecules and morphology: integrative taxonomic analysis of marine planktonic assemblages". Proposed co-convenors are Pennie Lindeque (UK), Lida Yebra (ES), and Ann Bucklin (USA).	SCICOM

Annex 3: WGIMT Terms of Reference 2017–2019

The **Working Group on Integrated Morphological and Molecular Taxonomy** (WGIMT), chaired by Naiara Rodriguez-Ezpeleta, Spain, and Elaine Fileman, UK, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2017	31 March	Boulogne-sur-Mer, France	Interim report by 1 June to SSGEPD	
Year 2018	24 March	Helsinki, Finland	Interim report by 1 June to SSGEPD	**Change of Chair** **Outgoing**: Ann Bucklin, USA **Incoming**: Naiara Rodriguez-Ezpeleta (ES), and Elaine Fileman (UK)
Year 2019			Final report by 1 June to SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
A	Ensure balanced morphological – molecular expertise among membership of WGIMT	a) Integrative taxonomy requires experts in both morphological and molecular taxonomic approaches. b,c) Members in common will facilitate coordination between WGIMT and SCICOM EGs and help ensure goals are met.	1,2,9,10,27,28,31	Year 1,2,3	WGIMT will continue to add new members, who are experts in morphological and molecular taxonomy for major zooplankton groups; 2 members in common with other SCICOM EGs.
B	Fully populate the WGIMT web platform with information, protocols and resources to support progress in research and development	a) Locating and accessing morphological and molecular taxonomic information can be difficult: some classical taxonomic references are out-of-print; molecular data are not released prior to publication. b,c) Open access to data and information will expand use of state-of-the-art molecular technologies (e.g., High-Throughput Sequencing) for integrative taxonomy of zooplankton.	27,28,31	Years 1,2,3	Complete and fully populate all areas of WGIMT.net web portal (Year 1). Complete specially-designed elements and deep links to support and promote use of technologies (Years 1, 2).
C	Initiate and support	a,b) Workshops, including ICES	27,28,31	Year 2	Design, organize

	provision of standards, training materials, and taxonomy workshops	Taxonomy Workshops, are very effective in engaging target audiences and ensuring trained technicians and researchers for applications in fisheries and ecosystem management. c) Co-sponsored workshops and meetings with other SCICOM EGs will increase impact and likelihood of application for advisory applications.			and offer integrative taxonomy workshops; request support via ICES Taxonomy Workshop funds (Year 2)
D	Demonstrate leadership in promoting and encouraging use of integrative taxonomic approaches for assessment of pelagic biodiversity	a,b,c) Integrative taxonomy is an emergent field; uses and applications for fisheries and ecosystem management should be explained in high-visibility settings in ICES and other organisations through special sessions	1,2,9	Years 1,2,3	Organize special sessions at national and international conferences: ASLO/TOS Ocean Sciences Meetings; ICES ASC (Years 1, 2, 3).
E	Advise on the implications of developments for marine science and management	b,c) Integrative taxonomy (e.g., 'library' of DNA sequences for accurately-identified species) can provide a foundation for genetic methods for assessing species, diversity and abundance in integrated ecosystem assessments. c) Standardized metagenetic data can fulfill requirements of biodiversity assessments (WGPME) and indicators defined in the Marine Strategy Framework Directive (WGAGFM).	28,31	Years 2,3	Report via SSGEPD and SCICOM EGs on promise, progress and pitfalls , of metagenetics (metabarcoding) for integrated ecosystem assessments (Years 1, 2, 3).
F	Publish high-profile peer-reviewed articles that provide documented evidence of advances in metagenetic analysis of zooplankton diversity, distribution, and abundance.	a) Stronger foundation and visibility in primary research literature is needed to establish the validity of metagenetic approaches for analysis of zooplankton diversity. b) Publication in peer-reviewed scientific journals will demonstrate validity of data, protocols, and results, and allow dissemination and new applications in ecosystem management.	1,2,9,10	Years 1, 2, 3	Publish two papers focused on integrative taxonomy of zooplankton using state-ofpthe-art molecular approaches, including overview, review, and perspective articles (Years 1, 2, 3).
G	Determine the status of microzooplankton time-series data collection within the ICES area.	a, c) Determine the status of microzooplankton time-series data collection within the ICES area, assess progress made in this area over the last ten years, and identify collaboration, gaps or overlap with other WGs	1,2,9,10	Years 2, 3	List of scientists and laboratories measuring microzooplankton groups within time-series datasets; data table to compare

		(WGZE, WGPME).			sampling and analysis methods, indicate which groups are regularly counted or routinely missed; database input; webpage update.
H	Review and evaluate methodologies used for metagenetic analysis of plankton.	a, c) Recommend development of standardized protocols for applications in fisheries management and ecosystem assessment.	1,2,9,10	Years 2, 3	Present findings at scientific conferences (Year 2); Report to EG members and ICES community (Year 2, 3); prepare manuscript for publication in peer-reviewed journal (Year 3).

Summary of the Work Plan

Year 1	Recruit new members for WGIMT, ensuring balanced membership (ToR a); fully populate all areas of web portal (ToR b). Cooperate with other SCICOM EGs to promote and accelerate use of state-of-the-art molecular approaches for biodiversity assessment and applications for management and assessment goals (ToR e).
Year 2	Carry out collaborative activities with other SCICOM EGs to promote integrative taxonomy (ToR c). Publish peer reviewed scientific articles on topics central to the WGIMT mission (ToR f). Compile and disseminate information on microzooplankton (ToR g).
Year 3	Recommend, encourage, and enable use of integrated morphological and molecular taxonomic analysis of zooplankton in integrated ecosystem assessments in ICES area seas (ToRs d,e,f,h).

Supporting information

Priority:	This Working Group will assist ICES and its Expert Groups with issues related to the development, dissemination and application of taxonomic knowledge and skills in support of Integrated Ecosystem Understanding. Accurate identification of species and characterization of species-level diversity are and will remain foundations of integrated ecosystem assessments of function and state. Integrated taxonomic approaches – including morphological, molecular, optical, and other – may enhance and accelerate progress toward rapid, automatable, and near-real-time identification of species for fisheries and integrated ecosystem assessments; detecting of the impacts of climate change on species diversity, distribution, abundance; and understanding alterations in food web structure and function, and associated biogeochemical cycles. The availability of and need for new technology and techniques in taxonomic analysis make WGIMT's goals and activities important and high priority.
Resource requirements:	No additional resources are requested or required for planned activities.
Participants:	The Expert Group now includes 42 members from 15 countries, with strong representation among experts in morphological and molecular taxonomic

	approaches. We continue to seek additional members, including especially members from partner ICES Working Groups and other scientists with needed expertise and knowledge. The goal is to maintain balance and coverage of varied taxonomic approaches (including morphological taxonomists for the full range of taxonomic groups) and ICES geographic regions.
Secretariat facilities:	None.
Financial:	No financial implications.
Linkages to ACOM and groups under ACOM:	None.
Linkages to other committees or groups:	WGIMT arose as a Study Group from the WGZE in response to perceived need, meeting in association with WGZE during 2012 and 2013. WGIMT will remain in close partnership with WGZE and is pursuing additional partnerships (e.g., WGPME, WGAGFM), while promoting and supporting integrated morphological and molecular taxonomy science for the benefit of the ICES science and advisory communities as a whole.
Linkages to other organizations:	The work of this group relates to and is connected to a diversity of other projects and organisations, e.g., EU DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing Good Environmental Status), BONUS BIO-C3 project, NOAA COPEPOD and COPEPODITE, GOBI, and others.

Annex 4: Agenda

Working Group on Integrated Morphological and Molecular Taxonomy

WGIMT – SSGEPD

Date: March 31, 2017

Meeting venue: Université du Littoral Côte d'Opale

Bassin napoléon – Quai Masset, Boulogne-sur-Mer, France

Video-conferencing access will be available via SKYPE

9:00 Welcome to the Meeting and Introductions; Review of the Agenda

9:15 Overview of WGIMT status and multi-annual ToRs 2017-2019

(Lead Ann Bucklin; Rapporteur Ann)

9:30 ToR B) Fully populate the WGIMT web platform with information, protocols and resources to support progress in research and development *(Lead Todd; Rapporteur Todd)*

Deliverables: Complete and fully populate all areas of WGIMT.net web portal (Year 1). Complete specially-designed elements and deep links to support and promote use of technologies (Years 1, 2).

- *Todd O'Brien: Interactive interface for photo gallery and COPEPEDIA plankton metabase*

- *Tone Falkenhaug: Next steps for molecular methods on WGIMT portal*

- *Jasmin Renz: Next steps for morphological methods on WGIMT portal*

- *Todd O'Brien: Populating the Literature Database on WGIMT.net*

10:15 Coffee Break

10:30 ToR E) Advise on the implications of developments for marine science and management

Deliverables: Report via SSGEPD and SCICOM EGs on promise, progress and pitfalls of metagenetics (metabarcoding) for integrated ecosystem assessments (Years 1, 2, 3). *(Rapporteur Ann)*

- *Naiara Rodriguez-Ezpeleta: Molecular approaches for innovative marine monitoring*

- *Piotr Margonski: Coordination with ICES SSGEPD and SCICOM WGs*

11:15 ToR C) Initiate and support provision of standards, training materials, and taxonomy workshops

Deliverables: Design, organize and offer integrative taxonomy workshops; request support via ICES Taxonomy Workshop funds (Year 2) *(Rapporteur Jasmin)*

- *Antonina dos Santos: ICES Plankton Leaflets*

- *Maria Grazia Mazzocchi: Taxonomy workshop proposal and planning suggestions*

12:00 **Discussion and election of new WGIMT chair**

(Lead Ann Bucklin; Rapporteur Ann)

12:30 LUNCH

2:00 ToR D) Demonstrate leadership in promoting and encouraging use of integrative taxonomic approaches for assessment of pelagic biodiversity

Deliverables: Organize special sessions at national and international conferences: ASLO/TOS Ocean Sciences Meetings; ICES ASC (Years 1, 2, 3). *(Rapporteur Elvire)*

- *Astthor Gislason: WGIMT contributions to ZPS-2016 (Bergen, Norway)*

- *Ann Bucklin: ICES 2017 Theme Session on Metabarcoding Microbes to Mammals*

2:30 ToR F) Publish high-profile peer-reviewed articles that provide documented evidence of advances in metagenetic analysis of zooplankton diversity, distribution, and abundance.

Deliverables: Publish two papers focused on integrative taxonomy of zooplankton using state-of-the-art molecular approaches, including overview, review, and perspective articles (Years 1, 2, 3).

- *Lidia Yebra: Summary of publications by WGIMT members related to WG mission and goals*

- *Rapporteur Joerg*

3:00 Updates on related research and publications from WGIMT members

3:30 Coffee Break

3:45 ToR A) Ensure balanced morphological – molecular expertise among membership of WGIMT

Deliverables: WGIMT will continue to add new members, who are experts in morphological and molecular taxonomy for major zooplankton groups; 2 members in common with other SCICOM EGs

- *Maria Grazia Mazzocchi, Elaine Fileman, Agata Weydmann: WGIMT membership approaches*

- *Rapporteur Tone*

4:15 Looking ahead to the future:

Session proposals for ICES ASC 2018 meeting

Discussion of new ToRs for WGIMT

Action Items and Planning for the Year Ahead

(Lead Ann Bucklin; Rapporteur Peter)

5:30 **ADJOURN**

Annex 5: ASC 2018 Theme Session Proposal

Title: Molecules and morphology: integrative taxonomic analysis of marine planktonic assemblages

Co-conveners:
Pennie Lindeque (Plymouth Marine Laboratory, UK)
Lidia Yebra (Instituto Español de Oceanografía, Spain)
Ann Bucklin (University of Connecticut, USA)

Abstract

Integrative taxonomy aims to delimit biodiversity from multiple and complementary perspectives: phylogeography, morphology, population genetics, ecology, development, and behaviour, among others. Applied to marine planktonic assemblages, the overarching goal of this emergent science is to yield new understanding of the taxonomy, systematics, and biodiversity of marine life. Assessment of planktonic diversity via high-throughput sequencing of environmental samples or metabarcoding (i.e., large-scale analysis of taxon richness via the analysis of homologous genes) is proving to be increasingly accurate, reliable and cost-effective. However, comparison and combination with classical morphological taxonomic analysis of plankton samples will continue to be necessary and important. Although the taxonomy and phylogeny of some planktonic groups may eventually be revised with the addition of molecular characters, traditional approaches based on morphology will not be replaced, only enhanced and augmented. Near-future prospects include sophisticated, powerful, and integrative analysis of morphological, molecular, biochemical, ecological, and geographic data to characterize planktonic biodiversity throughout the global ocean. Remaining challenges for integrative taxonomy include consistent discrimination of species – even closely related, cryptic, and rare species – based on high-throughput sequencing and accurate identification of taxa by comparison with reference sequence databases based on specimens identified by morphological taxonomic experts. This session will examine a broad range of methodologies, provide overviews of recent results using diverse types of data, and encourage discussion on opportunities and challenges of integrative taxonomy of marine planktonic assemblages.

Suggested topics may include:

- Novel approaches to assessing the 'hidden diversity' of marine planktonic communities
- Meeting the challenge of rapid and accurate detection of species-level diversity
- Examination of trophic relationships and food web structure
- Use of environmental DNA (eDNA) analyses for analysis of biodiversity
- Role of integrative taxonomy in ecosystem assessment and management

Suggested theme session format: Oral, poster presentations; panel discussion

Expected participation: ICES community scientists and managers

Linkages to ICES Strategic Plan: Goals 1 and 2 of the ICES Strategic Plan

Linkages to ICES Steering Groups and/or Advisory Committee (if relevant)

- Novel genetic technologies for integrated ecosystem assessment and management (SSGEPD)

- New insights into the drivers and consequences of ecosystem processes and dynamics (SSGEPD)