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SCICOM STEERING GROUP ON ECOSYSTEM PROCESSES AND DYNAMICS

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

18 March 2016

Lisbon, Portugal

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

The ICES Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT) met annually during the 2014–2016 period: 28 March 2014 in Reykjavik, Iceland; 17 and 20 March 2015 in Plymouth, UK; and 18 March 2016 in Lisbon, Portugal. During each meeting, the 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 42 members from 15 countries; reflecting addition of new members each year since 2013. The continuing growth is consistent with ToR (a) to expand WGIMT membership and welcome new members who develop and use molecular and/or morphological approaches to taxonomic analysis of zooplankton. Progress was reviewed in the continuing development and implementation of the WGIMT web platform for promotion and exchange of relevant scientific information for the morphological, molecular, and optical elements (ToR (b)), as well as new elements, including a photo gallery of living zooplankton and literature database.

WGIMT has continued work to initiate and support provision of standards, training materials, and taxonomy workshops through organized workshops (ToR (c)). One workshop, *SAHFOS-MBA Zooplankton Taxonomy Workshop*, exemplifying the WGIMT integrative taxonomic approach was held during 22–26 June 2015 in Plymouth, UK. WGIMT promoted and encouraged the continuing integration of molecular and morphological taxonomy by organizing special sessions at national and international conferences, including ICES 2015 ASC, ICES-PICES Zooplankton Production Symposium (2016), ASLO/TOS Ocean Sciences Meeting (February 2014 and 2016), among others (ToR (d)).

WGIMT is seeking avenues via SSGEPD and other SCICOM EGs to advise on implications and applications of integrative taxonomy for marine science and management (ToR (e)). Due to insufficient resources for WGIMT activities, proposed cooperation of WGIMT with WGITMO and WGBOSV (ToR (f)) was removed by mutual agreement of the WGs. During 2014–2016, WGIMT members published more than 20 peer-reviewed articles directly related to the core mission and goals of the EG, including a forward-looking HORIZONS article assessing the progress and promise of integrative morphological and molecular taxonomy of zooplankton, specifically metabarcoding for assessment of zooplankton diversity (ToR (g)).

WGIMT is recommending continuation for another 3-year term and is submitting a draft resolution for new multi-annual 2017–2019 ToRs. WGIMT proposes to meet in association with the Working Group on Zooplankton Ecology (WGZE) at IFREMER (Boulogne-sur-Mer, France) on 31 March 2017. Additional work will be carried out by correspondence and videoconferencing

1 Administrative details

Working Group name

Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT)

Year of Appointment within current cycle

2014

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

3

Chair(s)

Ann Bucklin, USA

Meeting venue

Lisbon, Portugal

Meeting dates

28 March 2014, Reykjavik, Iceland; 14 participants (plus 5 via SKYPE)

17 and 20 March 2015, Plymouth, UK; 16 participants (plus 2 via SKYPE)

18 March 2016, Lisbon, Portugal; 26 participants (plus 2 via SKYPE)

2 Terms of Reference a) – z)

ToR (a) Expand membership of WGIMT;

ToR (b) Develop a web platform for promotion and exchange of relevant scientific information;

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

ToR (d) Promote and encourage the continuing integration of molecular and morphological taxonomy;

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

ToR (f) Cooperate with WGITMO and WGBOSV to encourage and facilitate application of molecular protocols for detection and identification of introduced and transported species in ballast water;

ToR (g) Publish peer-reviewed articles on diverse aspects of integrative (morphological and molecular) taxonomy of zooplankton.

3 Summary of Work plan

ToR (a) WGIMT will include experts in both morphological and molecular taxonomy for major zooplankton groups; 2 members in common with ACOM EGs (Year 1).

ToR (b) WGIMT.net web portal designed, established (Year 1), populated (Year 2).

- 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) SAHFOS-MBA Zooplankton Taxonomy Workshop (2015); ICES Taxonomy Workshop on: *Future of Integrative Taxonomy* (2016).

ToR (d) Organize special sessions at national and international conferences, including Ocean Sciences Meetings (2016), ICES ASC (2016), others.

ToR (e) Report via SSGEPD and ACOM EGs on uses of integrative taxonomy (e.g., environmental sequencing or metagenetics) for integrated ecosystem assessment (Years 2,3). Report on uses of metagenetic indicators to WGAGFM (Year 2).

ToR (f) Define (Year 1), carry out (Year 2), and publish (Year 3) results of collaborative activities with WGITMO/WGBOSV. Participate in WGITMO-WGBOSV annual meetings (Years 1, 2, 3). Provide identifying DNA sequences for invasive species listed on AquaNIS (Year 2).

ToR (g) Publish two papers related to WGIMT (Years 2, 3). Publish review article on integrative morphological and molecular taxonomic approaches for zooplankton (Year 2).

4 Summary of Achievements of the WG during 2014–2016

- WGIMT comprised 22 members as of March 2013 (ToR a). Membership increased to 31 in 2014, 36 in 2015, and 42 in 2016. A number of WGIMT members are concurrently members of other ICES SCICOM WGs, including WGZE, WGPME, WGBOSV, WGITMO, and WGAGFM.
- The WGIMT.net web portal has been designed and implemented, expanded and updated (ToR b). The site provides general information about WGIMT and the WG's mission areas, as well as specific information was two major topic areas:
    - Morphological methods, including an overview; identification keys, with a collection of web links and literature references; photo gallery, with over 275 photographs of plankton stored in COPEPEDIA (see

http://copepedia.org/), a relational taxonomic database; and optical methods, with examples of eleven different optical sampling instruments.

    - Molecular methods, including an overview; tabular presentation of over 100 PCR and sequencing primers and protocols; and literature, with a listing of over 40 relevant publications.

- WGIMT members contributed significantly to a successful and productive interactive training workshop, *SAHFOS-MBA Crustacean Zooplankton Taxonomy Workshop* (22–26 June 2015, Plymouth, UK), covering classical morphological identification and molecular techniques (see http://www.sahfos.ac.uk/zooplankton-2015.aspx); (ToR c).
- ICES Zooplankton Identification Leaflets are being updated with oversight from ICES PubCom and new editors, Antonina Dos Santos (PT) and Claudia Castellani (UK), who are WGZE and WGIMT members (ToR c).
- WGIMT members served as organizers, co-convenors, and invited speakers for theme sessions related to WGIMT mission areas at international meetings (ToR d):
    - ICES 2013 ASC (September, 2013, Reykjavik, Iceland): Session F. Complexity and structure of planktonic foodwebs: who really eats whom? Convenor(s): Elaine Fileman (UK), Ann Bucklin (USA), Pennie Lindeque (UK), Janna Peters (Germany)
    - ASLO/AGU/TOS Ocean Sciences Meeting (February 2014, Honolulu, USA): Session 120. Integrative taxonomy of marine animals: progress, prospects, and pitfalls. Convenor(s): Ann Bucklin (USA)
    - ICES 2015 ASC (Copenhagen, Denmark):
        - Session S. Basin-scale dynamics at lower trophic levels in the North Atlantic. Convenor(s): Astthor Gislason (Iceland), Claudia Castellani (UK), Peter Wiebe (USA)
        - Session P: How to hit an uncertain, moving target: achieving good environmental status under the Marine Strategy Framework Directive. Convenor: Antonina dos Santos (PT)
- ICES/PICES 2016 Zooplankton Production Symposium (May 2016; Bergen, Norway):
    - Session 1. Application of optical and acoustical methods in zooplankton studies, Convenor(s): Mark Benfield (USA)
    - Session 2. Response of zooplankton communities to changing ocean climate, Convenor(s): Todd O'Brien (USA) and Tone Falkenhaug (Norway); invited speaker(s): Peter Wiebe (USA)
    - Session 4. Zooplankton diversity in the oceans by integrative morphological and molecular techniques, Convenor(s): Ann Bucklin (USA); invited speaker(s): Naiara Rodriguez-Ezpeleta (ES)
    - Workshop 2. ICES PICES cooperative research initiative - towards a global measurement of zooplankton production. Convenor(s): Lidia Yebra (ES)

  - Workshop 4. Effects of microplastics on zooplankton, Convenor(s): Elaine Fileman (UK) and Maiju Lehtiniemi (FIN); invited speaker: Pennie Lindeque (UK)
  - Workshop 6. A hands-on introduction to time series analysis, visualization, and inter-comparison of plankton survey data, Convenor(s): Todd O'Brien (USA)
  - Workshop 7. Toward a taxonomically-comprehensive global reference database for DNA barcodes of marine zooplankton, Convenor(s): Tone Falkenhaug (NO) and Silke Laakmann (DE); invited speaker: Ann Bucklin (USA)
- Discussed joint activities and ToRs with other SCICOM WGs on topics of common interest. WGAGFM shares focus on uses of metagenetics for integrated ecosystem assessment; agreement to revisit possible cooperation for next reporting period for both WGs during 2017. WGPME shares focus on analysis of biodiversity using metabarcoding approaches; will submit a joint theme session proposal for ICES 2017 ASC and discuss collaborative proposals for workshops and symposia (ToR e).
- DNA barcode sequences for invasive and non-indigenous species were added to the AquaNIS website (see http://www.corpi.ku.lt/databases/index.php/aquanis by WGITMO/WGBOSV (ToR f).
- WGIMT members published papers in the peer-reviewed scientific literature on topics central to the WGIMT mission (ToR g).

2013

Laakmann, S., G. Gerdts, R. Erler, T. Knebelsberger, P. Martinez Arbizu, and M.J. Raupach (2013) Comparison of molecular species identification for North Sea calanoid copepods (Crustacea) using proteome fingerprints and DNA sequences. Molec. Ecol. Res. doi: 10.1111/1755-0998.12139

Laakmann, S., and S. Holst (2013) Emphasizing the diversity of North Sea hydromedusae by combined morphological and molecular methods. J. Plankton Res. 36: 64–76. doi:10.1093/plankt/fbt078

Lehtiniemi, M., E. Gorokhova, S. Bolte, H. Haslob, B. Huwer, *et al.* (2013) Distribution and reproduction of the Arctic ctenophore *Mertensia ovum* in the Baltic Sea. Mar. Ecol. Progr. Ser. 491: 111–124

Lindeque, P.K., H.E. Parry, R.A. Harmer, P.J. Somerfield, and A. Atkinson (2013) Next Generation Sequencing reveals the hidden diversity of zooplankton assemblages. PLoS ONE 8: e81327.

Majaneva, S. and M. Majaneva (2013) Cydippid ctenophores in the coastal waters of Svalbard: is it only *Mertensia ovum*? Polar Biol. doi:10.1007/s00300-013-1377-6

Matzen da Silva, M., A. dos Santos, M.R. Cunha, F.O. Costa, S. Creer, and G.R. Carvalho (2013) Investigating the molecular systematic relationships amongst selected *Plesionika* (Decapoda: Pandalidae) from the Northeast Atlantic and Mediterranean Sea. Marine Ecology 34:157-170. doi:10.1111/j.1439-0485.2012.00530.x.

2014

Aarbakke, O.N.S., A. Bucklin, C. Halsband, and F. Norrbin (2014) Comparative phylogeography and demographic history of five sibling species of *Pseudocalanus* (Copepoda: Calanoida) in the North Atlantic Ocean. J. Exp. Mar. Biol. Ecol. 461: 479-488

Blanco-Bercial, L., A. Cornils, N.J. Copley, and A. Bucklin (2014) DNA barcoding of marine copepods: assessment of analytical approaches to species identification. PLOS-Currents Tree of Life [2014 June 23]

Cornils, A. (2014) Non-destructive DNA extraction for small pelagic copepods to perform integrative taxonomy. J. Plankton Res. doi:10.1093/plankt/fbu105

Pearman, J.K., M.M. El-Sherbiny, A. Lanzén, A.M. Al-Aidaroos, and X. Irigoien (2014) Metagenetic analysis of Red Sea zooplankton diversity. Front. Marine Sci. doi:10.3389/fmars.2014.00027

Smolina, I., S. Kollias, M. Poortvliet, T.G. Nielsen, P. Lindeque, C. Castellani, E.F. Møller, L. Blanco-Bercial, and G. Hoarau (2014) Genome- and transcriptome-assisted development of nuclear insertion/deletion markers for *Calanus* species (Copepoda: Calanoida) identification Molec. Ecol. Res. doi:10.1111/1755-0998.12241

Torres, A.P., F. Palero, A. dos Santos, P. Abelló, E. Blanco, A. Boné, and G. Guerao (2014) Larval stages of the deep-sea lobster *Polycheles typhlops* (Decapoda, Polychelida) identified by DNA analysis: morphology, systematic, distribution and ecology. Helgoland Marine Research, 68:379-397. doi:10.1007/s10152-014-0397-0

2015

Albaina, A., X. Irigoien, U. Aldalur, G. Boyra, M. Santos and A. Estonba (2015) Macrozooplankton predation impact on anchovy (*Engraulis encrasicolus*) eggs mortality at the Bay of Biscay shelf break spawning centre. ICES J. Mar. Sci. 72, 1370-1379

Albaina, A., X. Irigoien, U. Aldalur, U. Cotano, M. Santos, G. Boyra and A. Estonba (2015) A real-time PCR assay to estimate invertebrate and fish predation on anchovy eggs in the Bay of Biscay. Progr. Oceanogr. 131, 82–99.

Bucklin, A., D.J. McGillicuddy, P.H. Wiebe and C.S. Davis (2015) Habitat usage by the cryptic copepods *Pseudocalanus moultoni* and *P. newmani* on Georges Bank (Northwest Atlantic). Cont. Shelf Res. 111: 83-94

Cornils, A. and B. Wend-Heckmann (2015) First report of the planktonic copepod *Oithona davisae* in the northern Wadden Sea (North Sea): Evidence for recent invasion? Helgol Mar Res. doi:10.1007/s10152-015-0426-7

Mohrbeck, I., M.J. Raupach, P. Martínez Arbizu, T. Knebelsberger, S. Laakmann (2015) High-throughput sequencing - The key to rapid biodiversity assessment of marine metazoa? PLoS ONE, doi:10.1371/journal.pone.014034.

Viñas, M.D., L. Blanco-Bercial, A. Bucklin, H. Verheye, J. Guilherme, F. Bersano and S. Ceballos (2015) Phylogeography of the copepod *Calanoides carinatus* s.l. (Krøyer) reveals cryptic species and delimits *C. carinatus* s.s. distribution in SW Atlantic Ocean. J. Exp. Mar. Biol. Ecol. 468: 97-104

2016

Abad, D., A. Albaina, M. Aguirre, A. Laza-Martínez, I. Uriarte, A. Iriarte, F. Villate and 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

Albaina, A, Aguirre, M, Abad, D, Santos, M and Estonba, A (2016) 18S rRNA V9 metabarcoding for diet characterization: a critical evaluation with two sympatric zooplanktivorous fish species. Ecol. Evol., doi:10.1002/ece3.1986

Bucklin, A., P.K. Lindeque, N. Rodriguez-Ezpeleta, A. Albaina, and M. Lehtiniemi (2016) Metabarcoding of marine zooplankton: Progress, prospects and pitfalls. J. Plankton Res. doi:10.1093/plankt/fbw023

Nigro, L.M., M.V. Angel, K. Blachowiak-Samolyk, R.R. Hopcroft, and A. Bucklin (2016) Identification, discrimination, and discovery of species of marine planktonic ostracods using DNA barcodes. PLOS-One 11: e0146327.

Raupach, M.J., A. Barco, D. Steinke, J. Beermann, S. Laakmann, H. Neumann, T.C. Kihara, K. Pointner, A. Radulovici, A. Segelken-Voigt, C. Wesse, T. Knebelsberger (2015) The application of DNA barcodes for the identification of marine crustaceans from the North Sea and adjacent regions. PLoS ONE, doi:10.1371/journal.pone.0139421.

Wiebe, P.H., M. Benfield, A. Bucklin (2016) Zooplankton sample collection, preservation, and analysis. In: The Plankton Handbook, C. Castellani and M. Edwards [Eds.] Oxford University Press. (In press)

Wiebe, P.H., A. Bucklin, S. Kaartvedt, A. Røstad, L. Blanco-Bercial (2016) Vertical distribution and migration of euphausiid species in the Red Sea. J. Plankton Res. doi:10.1093/plankt/fbw038

- WGIMT members published a review article on integrative taxonomic approaches to characterizing zooplankton biodiversity in a peer-reviewed journal (ToR g).

Bucklin, A., P.K. Lindeque, N. Rodriguez-Ezpeleta, A. Albaina, and M. Lehtiniemi (2016) Metabarcoding of marine zooplankton: Progress, prospects and pitfalls. J. Plankton Res. HORIZONS doi:10.1093/plankt/fbw023

5 Final Report on ToRs, Workplan and Science Implementation Plan

ToR (a) Expand membership of WGIMT

The WGIMT membership has grown from a total of 22 members as of March 2013 to a total (as of 18 March 2016) of 42 members from 15 countries (Figure 1). 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.

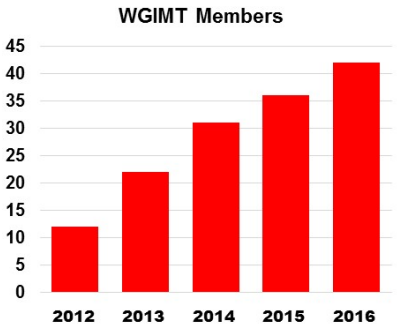
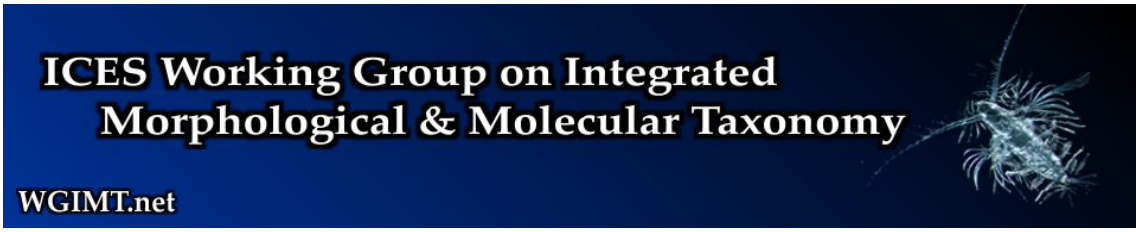


Figure 1. Numbers of WGIMT members by year.

ToR (b) Develop a web platform for promotion and exchange of relevant scientific information

The WGIMT.net web portal was established in Year 1 of the 3-year ToR cycle. The site 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 altogether 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

The WGIMT.net portal also features a *Meetings and Events* area that lists upcoming meetings and events of WGIMT-community interest. This section provided information and

backgrounds for the WGIMT-sponsored sessions and workshops held at the ICES/PICES 6th International Zooplankton Production Symposium (May 2016).

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

SAHFOS–MBA Zooplankton Taxonomy Workshop – 2015

Figure 3. Participants and instructors of the SAHFOS Crustacean Zooplankton Workshop (Plymouth, UK; 22–26 June 2015)

WGIMT member Claudia Castellani was the lead organizer for the very successful Crustacean Zooplankton Workshop held at the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS) and Marine Biological Association of the UK (MBA) during June 22-26, 2015 (Fig. 3). The workshop enrolled 22 students and included interactive training in both classical morphological identification and molecular techniques. Additional WGIMT members served as expert instructors, including Maria Grazia Mazzocchi (IT), Antonina Dos Santos (PT), Ann Bucklin (USA), Rowena Stern (UK).

ICES Zooplankton Identification Leaflets Updates

WGZE assumed leadership for this effort and requested that ICES PubCom appoint Antonina Dos Santos and Claudia Castellani as editors with primary responsibility and authority to update the ICES Zooplankton Identification Leaflets. The request was approved, and plans are in place to start work on the most common species in the ICES areas and the Mediterranean, with the assistance of taxonomic experts. A related goal is to designate the leaflets as data publications and ensure assignment of DOI numbers, so they can be cited and more easily accessed.

ToR (d) Promote and encourage the continuing integration of molecular and morphological taxonomy

- WGIMT members assumed leadership responsibility (as proposers and convenors) for theme sessions at international conferences, including the ICES 2013 and 2015 Annual Science Conferences, 2014 ASLO/AGU/TOS Ocean Sciences, and 2016 ICES-PICES Zooplankton Production Symposium.
- Time was reserved during all annual WGIMT meetings to allow members to present updates about their own research progress on topics related to the

WG's core mission. The group members view these updates as critically important to promote and encourage the continuing integration of molecular and morphological taxonomy, the purpose of this ToR. Updates presented included:

2014

- MetaCopepod: Designing an integrated DNA metabarcoding and image analysis approach to study and monitor biodiversity of zooplanktonic copepods, Panagiotis Kasapidis (GR)
- Hidden diversity of zooplankton: biodiversity assessment using next-generation sequencing, Pennie Lindeque (UK)
- Use of metabarcoding to calculate an AMBI (AZTI's Marine Biotic Index) for benthic macrofauna, Naiara Rodriguez-Ezpeleta (ES)
- High throughput amplicon sequencing to determine zooplankton diversity in the Red Sea, John Pearman (SA; presented by Ann Bucklin, USA)
- Toward metagenetic analysis of biodiversity of zooplankton communities, Ann Bucklin (USA)

2015

- Zooplankton diversity comparison using different metabarcoding approaches, Jon Corell (ES)
- Update on developments from AMBI (AZTI's Marine Biotic Index), Naira Rodriguez-Ezpeleta (ES)
- Review of recent papers comparing metabarcoding and morphological (microscopic) approaches to taxonomic analysis, Aitor Albaina Vivanco (ES; presented by Ann Bucklin, USA)

2016

- Metabarcoding of zooplankton for ecosystem assessment; Naiara Rodriquez and Jon Corell (ES)
- Inventory of marine Copepoda and Cladocera (Crustacea) in Norway (COPCLAD); Tone Falkenhaug (NO)
- Calanoid copepod diversity - a comparison of morphology, DNA sequence analyses and proteomic fingerprinting; Silke Laakmann (DE)
- MetaCopepod project; Panagiotis Kasapidis (GR; presented by Maria Grazia Mazzocchi, IT)
- WGPME questionnaire and paper on role of molecular methods for routine monitoring of marine eukaryotic microbes; Rowena Stern (UK)
- Characterization of the diet of the planktonic community in Málaga Bay (NW Alboran Sea); Lidia Yebra (ES)

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

ToR (e) Report via SSGEPD and ACOM EGs on uses of integrative taxonomy (e.g., environmental sequencing or metagenetics) for integrated ecosystem assessment in the context of the Marine Strategy Framework Directive (MSFD) (Years 2, 3). Report on uses of metagenetic indicators to WGAGFM (Year 2).

WGIMT recommended a joint ToR with WGAGFM related to examining the potential of metagenetics for biodiversity assessments and other parameters related to the implementation of ecosystem management in the context of the Marine Strategy Framework Directive (MSFD).

WGIMT is recommending 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.

ToR (f) Cooperate with WGITMO and WGBOSV to encourage and facilitate application of molecular protocols for detection and identification of introduced and transported species in ballast water

WGIMT requested that WGBOSV and WGITMO provide a prioritized list of invasive species by region, with suggestions of any preferences for a pilot project to ensure public availability of DNA barcodes for these species. It became apparent that the WGIMT focus on marine zooplankton was inconsistent with WGBOSV and WGITMO priorities and goals. Discussion continued and DNA barcodes were added to the AquaNIS website (Fig. 4). Plans for interchange of members at the WGs annual meetings were not possible, due to selection of the same meeting dates for both 2015 and 2016. In 2016, due to lack of progress, this joint ToR was removed by mutual agreement among the WGs.

ToR (g) Publish peer-reviewed articles on diverse aspects of integrative (morphological and molecular) taxonomy of zooplankton

WGIMT has a goal, consistent with ICES guidance, to publish peer-reviewed scientific papers on topics central to the WGIMT mission. We consistently exceeded our goal of 2 papers per year, with 6 papers in 2013, 6 papers in 2014, 6 papers in 2015, and 7 papers in 2016. PDFs are posted to the WGIMT SharePoint. A particular goal was the publication of an article providing a review or assessment of integrative taxonomic approaches. In 2016, five WGIMT members co-authored a position paper (Bucklin *et al.*, 2016) assessing the prospects for use of metagenetics for assessment of biodiversity, rapid detection of impacts of climate change, and applications for fisheries management and ecosystem assessment.

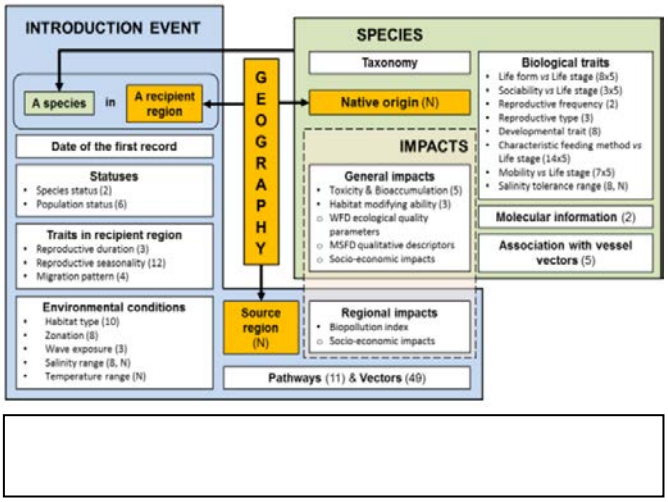


Figure 4. Excerpt from poster by M. Lehtiniemi, M., S. Olenin, H. Ojaveer, A. Bucklin (2016) on the AquaNIS information system with integrated DNA barcode information. ICES/PICES Zooplankton Production Symposium (Bergen, Norway).

6 Cooperation

Cooperation with other WG

WGIMT was established in 2014 by conversion of the Study Group of Morphological Molecular Taxonomy (SGIMT), which had been established in 2009 within the Working Group on Zooplankton Ecology (WGZE). Throughout these years, SGIMT and then WGIMT has maintained close functional ties to the WGZE, including a numbers of members in common and a continuing, and much-appreciated, annual invitation from WGZE to hold our meetings in association. This synergistic relationship and extensive cooperation has served WGIMT very well, and is expected to continue into the future.

WGIMT requested a joint ToR with WGBOSV/WGITMO in 2015, which was accepted. We sought to develop a joint pilot project to ensure public availability of DNA barcodes for high priority invasive and non-indigenous species. However, the WGIMT focus on marine zooplankton was inconsistent with WGBOSV/WGITMO priorities and goals, plans for interchange of members at the WGs annual meetings were not possible due to selection of the same meeting dates for both 2015 and 2016, and in 2016 the joint ToR was removed by mutual agreement among the WGs.

WGIMT recommended a joint ToR with WGAGFM related to examining the potential of metagenetics for biodiversity assessments and other parameters related to the implementation of ecosystem management in the context of the Marine Strategy Framework Directive (MSFD). Consideration of the ToR is being delayed until 2017.

WGIMT is recommending 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.

7 Summary of Working Group Self-Evaluation and Conclusions

WGIMT's primary contributions have focused on the ICES Science Plan Priorities #1, 2, 9, 10, 27, 28, and 31. WGIMT seeks to contribute to the ICES mission to analyze, recognize, and understand changes in community structure, species diversity, and population connectivity. Our novel approaches to characterization of species-level diversity may be expected to become a foundation for the assessment and management of ecosystem goods and services. The integrative morphological and molecular taxonomic and metagenetic approaches promoted by WGIMT are needed to develop historic baselines of population and community structure and to detect consequences of climate change. WGIMT seeks to promote new technologies and opportunities for observation and monitoring, and to establish of guidelines and quality standards for applications of metagenetics/ metabarcoding approaches.

WGIMT has shown significant success in working toward our goals and associated multi-annual ToRs for 2014–2016, including: expanding membership of WGIMT (ToR a); developing a web platform for promotion and exchange of relevant scientific information (ToR b); initiating and supporting provision of standards, training materials, and taxonomy workshops (ToR c); promoting and encouraging the continuing integration of molecular and morphological taxonomy (ToR d); and publishing peer-reviewed articles on diverse aspects of integrative (morphological and molecular) taxonomy of zooplankton (ToR g). Future plans include continued work on two ToRs for which progress has been negligible or less than desired, including: advising on the implications of developments for marine science and management (ToR e); and cooperating with other EGs (WGITMO, WGBOSV) to encourage and facilitate application of molecular protocols for detection and identification of introduced and transported species in ballast water (ToR f).

Importantly, the group sees a clear way forward toward further promotion of our scientific goals in support of the ICES Strategic Plan, and also anticipates implementation of our advisory goals through practical applications in ecosystem assessment and fisheries management. WGIMT future plans include targeted contribution toward quantifying the effects of climate change on regional ecosystems (ICES Science Plan Priority 3); understanding the influence of climate impacts from local to global and from seasonal to multidecadal space/time scales (ICES Science Plan Priority 4); quantifying the role of structural and functional diversity in marine ecosystems (ICES Science Plan Priority 5); and defining and quantifying North Atlantic Ecosystem Goods and Services (ICES Science Plan Priority 6).

WGIMT's future plans (see #10 above) include specific contributions to specific Science Plan Priorities that support the ICES Advisory process. In particular, WGIMT integrative taxonomic metagenetic / metagenomic approaches can contribute toward defining and quantifying North Atlantic Ecosystem Goods and Services (Science Plan Priority 8). WGIMT plans to work toward development of standardized metagenetic protocols for assessment of pelagic biodiversity can help provide priorities and specifications for data collection frameworks supporting IEA's (Science Plan Priority 20).

Annex 1: List of participants

WGIMT meeting in 2014

Participants in the 2014 annual meeting are indicated in the right-hand column: 14 members attended in person (Y); an additional four members joined via teleconference (V).

	First / Last Names	Email address	Function	Start date	Nomination	2014 Mtg
1	Christina Augustin	christina.augustin@io-warnemuende.de	Chair-invited Member	3/13/2013	Other	Y
2	Dorte Bekkevold	db@aqua.dtu.dk	Member	1/1/2011	DK	
3	Mark Benfield	mbenfie@lsu.edu	Chair-invited Member	2/19/2013	Other	
4	Leocadio Blanco-Bercial	leocadio@uconn.edu	Chair-invited Member	3/19/2014	Other	V
5	Ann Bucklin	ann.bucklin@uconn.edu	Chair	1/1/2012	Other	Y
6	Claudia Castellani	cxc@sahfos.ac.uk	Chair-invited Member	3/13/2013	Other	Y
7	Maria Alexandra Chicharo	mchichar@ualg.pt	Chair-invited Member	3/19/2014	Other	Y
8	Kathryn Cook	kathryn.cook@scotland.gsi.gov.uk	Chair-invited Member	2/19/2013	Other	Y
9	Astrid Cornils	Astrid.Cornils@awi.de	Chair-invited Member	2/19/2013	Other	
10	Elaine Fileman	ESE@pml.ac.uk	Chair-invited Member	2/19/2013	Other	Y
11	Astthor Gislason	astthor@hafro.is	Chair-invited Member	3/19/2014	Other	Y
12	Xabier Irigoien	Xabier.irigoyen@kaust.edu.sa	Chair-invited Member	2/19/2013	Other	
13	Panagiotis Kasapidis	kasapidi@hcmr.gr	Chair-invited Member	3/19/2014	Other	Y
14	Silke Laakmann	slaakmann@senckenberg.de	Chair-invited Member	2/19/2013	Other	
15	Maiju Lehtiniemi	maiju.lehtiniemi@ymparisto.fi	Chair-invited Member	3/14/2013	Other	Y
16	Pennie Lindeque	PKW@pml.ac.uk	Chair-invited Member	2/19/2013	Other	V
17	Amy Maas	amaas@whoi.edu	Chair-invited Member	2/19/2013	Other	
18	Sanna Majaneva	Sanna.majaneva@gmail.com	Chair-invited Member	3/14/2013	Other	V
19	Piotr Margonski	pmargon@mir.gdynia.pl	Chair-invited Member	2/19/2013	Other	
20	Maria Grazia Mazzocchi	grazia.mazzocchi@szn.it	Chair-invited Member	3/19/2014	Other	
21	Vijayalakshmi R. Nair	vijayalakshmi40@hotmail.com	Chair-invited Member	2/19/2013	Other	
22	Einar E. Nielsen	een@dfu.min.dk	Member	1/1/2011	DK	
23	Todd D. O'Brien	Todd.OBrien@noaa.gov	Chair-invited Member	2/19/2013	Other	Y
24	Janna Peters	janna.peters@uni-hamburg.de	Chair-invited Member	2/19/2013	Other	Y
25	Hildur Petursdottir	hildur@hafro.is	Chair-invited Member	3/19/2014	Other	Y
26	Uwe Piatkowski	upiatkowski@geomar.de	Chair-invited Member	2/19/2013	Other	
27	Jasmin Renz	jrenz@senckenberg.de	Chair-invited Member	2/19/2013	Other	
28	Naiara Rodriguez-Ezpeleta	nrodriguez@azti.es	Chair-invited Member	3/19/2014	Other	V
29	Antonina Santos	antonina@ipma.pt	Chair-invited Member	2/19/2013	Other	Y
30	Robertas Staponkus	ichtiandrus@gmail.com	Member	1/21/2013	LT	
31	Lidia Yebra	lidia.yebra@ma.ieo.es	Chair-invited Member	2/19/2013	Other	V
32	Peter H. Wiebe	pwiebe@whoi.edu	Chair-invited Member	3/19/2014	Other	Y

WGIMT meeting in 2015

16 members participated in the 2015 annual meeting in person (Y in the right-hand column); one additional member joined via teleconference (V).

	Name	Function	Country	2015
1	Aitor Albaina Vivanco	Chair-invited Member	Spain	
2	Amy Maas	Chair-invited Member	United States	
3	Ann Bucklin	Chair	United States	Y
4	Antonina dos Santos	Chair-invited Member	Portugal	Y
5	Arantza Iriarte	Chair-invited Member	Spain	Y
6	Astrid Cornils	Chair-invited Member	Germany	
7	Astthor Gislason	Chair-invited Member	Iceland	Y
8	Christina Augustin	Chair-invited Member	Germany	
9	Claudia Castellani	Chair-invited Member	United Kingdom	Y
10	Dorte Bekkevold	Member	Denmark	
11	Einar E. Nielsen	Member	Denmark	
12	Elaine Fileman	Chair-invited Member	United Kingdom	Y
13	Elvire Antajan	Chair-invited Member	France	Y
14	Hildur Pétursdóttir	Chair-invited Member	Iceland	
15	Janna Peters	Chair-invited Member	Germany	
16	Jasmin Renz	Chair-invited Member	Germany	Y
17	Kathryn Cook	Chair-invited Member	United Kingdom	Y
18	Leocadio Blanco-Bercial	Chair-invited Member	United States	
19	Lidia Yebra	Chair-invited Member	Spain	Y
20	Maiju Lehtiniemi	Chair-invited Member	Finland	Y
21	Maria Alexandra Chicharo	Chair-invited Member	Portugal	
22	Maria Grazia Mazzocchi	Chair-invited Member	Italy	Y
23	Mark Benfield	Chair-invited Member	United States	Y
24	Naiara Rodriguez-Ezpeleta	Chair-invited Member	Spain	V
25	Panagiotis Kasapidis	Chair-invited Member	Greece	
26	Pennie Lindeque	Chair-invited Member	United Kingdom	Y
27	Peter Wiebe	Chair-invited Member	United States	Y
28	Piotr Margonski	Chair-invited Member	Poland	
29	Robertas Staponkus	Member	Lithuania	
30	Sanna Majaneva	Chair-invited Member	Finland	
31	Sigrun Jonasdottir	Chair-invited Member	Denmark	
32	Silke Laakmann	Chair-invited Member	Germany	
33	Todd D. O'Brien	Chair-invited Member	United States	Y
34	Uwe Piatkowski	Chair-invited Member	Germany	
35	Vijayalakshmi R. Nair	Chair-invited Member	India	
36	Xabier Irigoien	Chair-invited Member	Saudi Arabia	

WGIMT meeting in 2016

24 members participated in the 2016 annual meeting in person (Yes, in the right-hand column); two members joined via teleconference (SKYPE).

Name	Parent Institute	Email	Country	Attend?
Aitor Albaina	University of the Basque Country	aitoralbaina@hotmail.com	Spain	Yes
Amy Maas	Bermuda Institute of Ocean Sciences	amy.maas@bios.edu	United States	
Ana Teresa Pereira	Portuguese Inst Sea and Atmosphere		Portugal	Yes
Andone Estonba	University of the Basque Country	andone.estonba@ehu.es	Spain	Yes
Ann Bucklin	University of Connecticut	ann.bucklin@uconn.edu	United States	Yes
Antonina Santos	Portuguese Inst Sea and Atmosphere	antonina@ipma.pt	Portugal	Yes
Astrid Cornils	Alfred-Wegener-Institute Foundation for Polar and Marine Research	Astrid.Cornils@awi.de	Germany	
Astthor Gislason	Marine Research Institute	astthor@hafro.is	Iceland	Yes
Cátia Bartilotti	Portuguese Inst Sea and Atmosphere	cbartilotti@ipma.pt	Portugal	Yes
Christina Augustin	Leibniz Institute for Baltic Sea Research Warnemünde	christina.augustin@io-warnemuende.de	Germany	
Claudia Castellani	Sir Alister Hardy Foundation for Ocean Science	cxc@sahfos.ac.uk	United Kingdom	Yes
Dorte Bekkevold	DTU Aqua - National Institute of Aquatic Resources	db@aqua.dtu.dk	Denmark	
Einar E. Nielsen	DTU Aqua - National Institute of Aquatic Resources	een@dfu.min.dk	Denmark	
Elaine Fileman	Plymouth Marine Laboratory	ESE@pml.ac.uk	United Kingdom	
Guida Camacho	Portuguese Inst Sea and Atmosphere		Portugal	Yes
Hildur Pétursdóttir	Marine Research Institute	hildur@hafro.is	Iceland	
Inês Dias	Portuguese Inst Sea and Atmosphere		Portugal	Yes
Inês Farias			Portugal	Yes
Iratxe Zarraonaindia	University of the Basque Country (UPV/EHU)	iratxe.zarraonaindia@ehu.es	Spain	Yes
Janna Peters	University of Hamburg	janna.peters@uni-hamburg.de	Germany	
Jasmin Renz	University of Hamburg	jrenz@senckenberg.de	Germany	Yes
Kathryn Cook	Marine Scotland Science	kathryn.cook@scotland.gsi.gov.uk	United Kingdom	Yes
Leocadio Blanco-Bercial	Bermuda Institute of Ocean Sciences	leocadio@bios.edu	United States	
Lidia Yebra	Instituto Español de Oceanografía	lidia.yebra@ma.ieo.es	Spain	Yes
Ligia Sousa	Portuguese Inst Sea and Atmosphere	ligia.sousa@ipma.pt	Portugal	Yes
Maiju Lehtiniemi	Finnish Environment Institute (SYKE)	maiju.lehtiniemi@ymparisto.fi	Finland	
Maria Alexandra Chicharo	University of Algarve	mchichar@ualg.pt	Portugal	
Maria Grazia Mazzocchi	Stazione Zoologica Anton Dohrn	grazia.mazzocchi@szn.it	Italy	Yes
Mark Benfield	Louisana State University	mbenfie@lsu.edu	United States	
Naiara Rodriguez-Ezpeleta	AZTI-Tecnalia	nrodriguez@azti.es	Spain	SKYPE
Panagiotis Kasapidis	Hellenic Centre of Marine Research (HCMR)	kasapidi@hcmr.gr	Greece	
Pennie Lindeque	Plymouth Marine Laboratory	PKW@pml.ac.uk	United Kingdom	
Peter Wiebe	Woods Hole Oceanographic Institution	pwiebe@whoi.edu	United States	Yes
Piotr Margonski	National Marine Fisheries Research Institute	pmargon@mir.gdynia.pl	Poland	Yes
Raquel Marques	Portuguese Inst Sea and Atmosphere	raquel.marques@ipma.pt	Portugal	Yes
Robertas Staponkus	Institute of Ecology Nature Research Centre	ichtiandrus@gmail.com	Lithuania	
Rowena Stern	Sir Alister Hardy Foundation for Ocean Science	rost@sahfos.ac.uk	United Kingdom	SKYPE
Sanna Majaneva	Finnish Environment Institute (SYKE)	Sanna.majaneva@gmail.com	Finland	
Seona Wells	Marine Scotland Science	s.r.wells.09@aberdeen.ac.uk	United Kingdom	Yes
Sigrun Jonasdottir	DTU Aqua - National Institute of Aquatic Resources	sjo@aqua.dtu.dk	Denmark	
Silke Laakmann	Research Institute Senckenberg by the Sea	slaakmann@senckenberg.de	Germany	Yes
Todd D. O'Brien	NOAA Fisheries	Todd.OBrien@noaa.gov	United States	Yes
Tone Falkenhaug	Institute of Marine Research	tonef@imr.no	Norway	Yes
Uwe Piatkowski	Leibniz-Institut für Meereswissenschaften	upiatkowski@geomar.de	Germany	
Vijayalakshmi R. Nair	National Institute of Oceanography	vijayaapril2014@gmail.com	India	
Xabier Irigoien	King Abdullah University for Science and Technology	Xabier.irigoyen@kaust.edu.sa	Saudi Arabia	

Annex 2: Recommendations

Recommendation	Adressed to
1. WGIMT requests continuation for another 3-year term 2017–2019 and is submitting a resolution with multi-annual Terms of Reference for this period.	SSGEPD
2. WGIMT recommends that the 2017 meeting be held on 31 March 2017 at IFREMER, Boulogne-sur-Mer, France. WGIMT proposes to meet in association with WGZE, which is scheduled for 27–30 March 2017.	WGZE
3. WGIMT recommends expanded coordination with WGPME and requests their consideration of a joint ToR 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.	WGPME
4. With WGPME and WGZE, WGIMT is proposing a Theme Session for the ICES 2017 Annual Science Conference entitled, *Microbes to mammals: metabarcoding of the marine pelagic assemblage*. Proposed co-convenors are Ann Bucklin (USA), Rowena Stern (UK), Katja Metfies (DE).	SCICOM

Annex 3: Draft Multi-annual Terms of Reference for 2017–2019

The **Working Group on Integrated Morphological and Molecular Taxonomy** (WGIMT), chaired by Ann Bucklin, USA, 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			Interim report by	
Year 2019			Final report by	

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
A	Maintain 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 include experts in both morphological and molecular taxonomy for major zooplankton groups; 2 members in common with other SCICOM EGs.
B	Maintain and enhance the WGIMT web platform for promotion and exchange of relevant scientific information	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) Easier access to data and information will encourage use of integrative taxonomic approaches.	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, and enhance impact and use of portal (Years 1, 2).
C	Initiate and support provision of standards, training materials,	a,b) Workshops, including ICES Taxonomy Workshops, are very effective in engaging target audiences	27,28,31	Year 2	Organize and hold integrative taxonomy workshops;

	and taxonomy workshops	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.			request support via ICES Taxonomy Workshop funds (Year 2)
D	Promote and encourage the continuing integration of molecular and morphological taxonomy	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 uses of integrative taxonomy (e.g., environmental sequencing or metagenetics) for integrated ecosystem assessment (Years 1, 2, 3).
F	Publish peer-reviewed articles to provide foundation for core mission areas in integrative (morphological and molecular) taxonomy of zooplankton.	a) Stronger foundation and visibility in primary research literature is needed to establish the field of integrative taxonomy. b) Publication in peer-reviewed literature needed to demonstrate validity of data, protocols, and results for application to fisheries and ecosystem management.	1,2,9,10	Years 1, 2, 3	Publish two papers, including overview, review, and perspective articles, related to WGIMT ToRs (Years 1, 2, 3).

Summary of the Work Plan

Year 1	Maintain balanced membership (ToR a); fully populate all areas of web portal (ToR b). Cooperate with other SCICOM EGs (WGAGFM, WGPME) to ensure application of integrative taxonomy for management and assessment goals (ToR e).
Year 2	Carry out collaborative activities with other SCICOM EGs to promote integrative taxonomy (ToR c) and support mission areas and approaches in common with other EGs (ToR f). Publish peer reviewed scientific articles on topic central to the WGIMT mission (ToR g).
Year 3	Facilitate, 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,g).

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. Additional members are welcome, 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	The work of this group relates to and is connected to a diversity of other projects

other organizations:	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: Theme Session Proposal: ICES 2017 Annual Science Conference

Title: Microbes to mammals: metabarcoding of the marine pelagic assemblage

Co-convenors: Ann Bucklin (USA), Rowena Stern (UK), Katja Metfies (Germany)

Sponsored by WGIMT, WGPME, WGZE

Abstract

Molecular approaches are revolutionizing analysis and assessment of marine pelagic assemblages and enabling simultaneous detection of diversity from microbes to mammals. Emerging results indicate that global estimates of pelagic diversity will markedly increase with more accurate detection of rare, cryptic and introduced species, as well as higher resolution of time/space patterns. As high-throughput DNA sequencing (HTS) becomes more accessible and less expensive, use of metabarcoding (i.e., large-scale taxonomic identification of complex environmental samples via analysis of orthologous DNA regions) may be expected to expand into numerous applications in ocean research, monitoring, and management and may be critically important in allowing rapid detection and description of the impacts of climate change on pelagic biodiversity and biogeography.

Among the challenges remaining for reliable and routine application of metabarcoding are evaluation and comparison of results using different genes and gene regions; impacts of degraded DNA (e.g., environmental DNA and DNA recovered from gut contents); and continued development of taxonomically comprehensive reference databases for all gene regions. A particular need is to move metabarcoding applications from identification and detection of taxa to their quantification in terms of abundance and/or biomass.

Despite the remarkable promise of metabarcoding in yielding new understanding and appreciation for global patterns of biodiversity, it is critically important to maintain expertise and capacity in morphological taxonomy across the many groups represented in the marine pelagic assemblage.

Applications for ecosystem observation will require that metabarcoding approaches are validated, ground-truthed, and standardized. Such integrative morphological and molecular taxonomic approaches will provide a foundation and future of research, monitoring and management of the pelagic realm.

Topics of particular interest for submitted abstracts include:

- Comparison of morphological and metabarcoding analyses; accuracy and resolution of MOTU (Molecular Operational Taxonomic Unit) designations.
- Environmental DNA (eDNA) analysis.
- Prospects for metabarcoding analysis of species-level biodiversity for metazoans.
- Metabarcoding analysis of trophic interactions and pelagic food-web dynamics.
- Approaches toward quantitative analysis of taxon abundance or biomass.
- Applications for time-series collections and long-term ocean observation.

- Standardization and/or intercomparison of protocols for ecosystem monitoring and assessment, including calculation of biotic indices and detection of introduced invasive species.

Annex 5: Copy of Working Group Self-Evaluation

1) Working Group name: Working Group on Integrated Morphological and Molecular Taxonomy (WGIMT)
2) Year of appointment: 2014
3) Current Chairs: Ann Bucklin, USA
4) Venues, dates and number of participants per meeting:

   - Reykjavik, Iceland; 28 March 2014, 13 participants (plus 5 via SKYPE)

   - Plymouth, UK; 17, 20 March 2015, 16 participants (plus 2 via SKYPE)

   - Lisbon, Portugal; 18 March 2016, 26 participants (plus 2 via SKYPE)

WG Evaluation

5) If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.

Science Plan Priority 1. Assess the physical, chemical and biological state of regional seas and investigate the predominant climatic, hydrological and biological features and processes that characterise regional ecosystems.

WGIMT seeks to contribute to the ICES mission to analyze, recognize, and understand changes in community structure, species diversity, and species phenology and productivity. Furthermore, the group contributes to ICES efforts to understand and predict how these characteristics will affect foodwebs, trophic relationships as well as the transfers and cycles of nutrients, chemical elements, energy, and biological production.

Science Plan Priority 2. Quantify the nature and degree of connectivity and separation between regional ecosystems.

WGIMT approaches include molecular population genetic, population genomic, metagenetic (metabarcoding and environmental sequencing) and metagenomic analysis of zooplankton species and assemblages. These analyses lend themselves to quantitative estimates of population connectivity, directional exchange (migration), micro-evolutionary divergences of the pelagic assemblage of regional ecosystems. WGIMT seeks to standardize metagenetic analysis of biodiversity for applications for ecosystem monitoring; such standardization will also allow comparisons of connectivity between ICES regional seas.

Science Plan Priority 9. Identify indicators of ecosystem state and function for use in the assessment and management of ecosystem goods and services.

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 to-

ward rapid, automatable, and near-real-time identification of species for fisheries and integrated ecosystem assessments.

Science Plan Priority 10. Develop historic baseline of population and community structure and production to be used as a basis for population and system level reference points.

The integrative taxonomic and metagenetic approaches promoted by WGIMT are appropriate and useful analysis of collections from time-series stations and monitoring surveys to explore responses of key species to climate change.

Science Plan Priority 27. Identify knowledge and methodological monitoring gaps and develop strategies to fill these gaps.

Integrative taxonomy is an emergent field; WGIMT seeks to explain and promote the uses and applications of these novel approaches for fisheries and ecosystem management in high-visibility settings within ICES and the broader scientific and advisory communities.

Science Plan Priority 28. Promote new technologies and opportunities for observation and monitoring and assess their capabilities in the ICES context.

The primary goal of WGIMT is integrative morphological-molecular taxonomic analysis as a foundation for assessing species diversity, distribution and abundance of the marine zooplankton assemblage, which are fundamental properties of the biological state of regional seas. WGIMT seeks to develop and promote new technologies and techniques for species-level taxonomic analysis to meet ICES goals for integrated ecosystem assessment and prediction of impacts of climate change.

Science Plan Priority 31. Ensure the development of best practice through establishment of guidelines and quality standards for (a) surveys and other sampling and data collection systems; (b) external peer reviews of data collection programmes and c) training and capacity building opportunities for monitoring activities.

ICES Taxonomy Workshops are very effective in engaging the target audience and ensuring trained technicians and researchers for applications in fisheries and ecosystem management. Co-sponsored workshops and meetings with ACOM EGs will provide cross-training and establish organic links between science and advice.

6) In bullet form, highlight the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc.

Summary of Achievements of the WG during 2014–2016

- WGIMT comprised 22 members as of March, 2013 (ToR a). Membership increased to 31 in 2014, 36 in 2015, and 42 in 2016. A number of WGIMT members are concurrently members of other ICES SCICOM WGs, including WGZE, WGPME, WGBOSV, WGITMO, and WGAGFM.

- The WGIMT.net web portal has been designed and implemented, expanded and updated (ToR b). The site provides general information about WGIMT and the WG's mission areas, as well as specific information in two major topic areas: morphological methods and molecular methods.
- WGIMT members contributed significantly to a successful and productive interactive training workshop, *SAHFOS-MBA Crustacean Zooplankton Taxonomy Workshop* (22–26 June 2015, Plymouth, UK), covering classical morphological identification and molecular techniques (see http://www.sahfos.ac.uk/zooplankton-2015.aspx); (ToR c).
- ICES Zooplankton Identification Leaflets are being updated with oversight from ICES PUBCOM and new editors, who are WGIMT members (ToR c).
- WGIMT members served as organizers, co-convenors, and invited speakers for theme sessions related to WGIMT mission areas at international meetings (ToR d):
    - ICES 2013 ASC (September 2013, Reykjavik, Iceland): Session F. Complexity and structure of planktonic foodwebs: who really eats whom?
    - ASLO/AGU/TOS Ocean Sciences Meeting (February 2014, Honolulu, USA): Session 120. Integrative Taxonomy of Marine Animals: Progress, Prospects and Pitfalls.
    - ICES 2015 ASC (Copenhagen, Denmark): Session S. Basin-scale dynamics at lower trophic levels in the North Atlantic; and Session P: How to hit an uncertain, moving target: achieving Good Environmental Status under the Marine Strategy Framework Directive.
    - ICES/PICES 2016 Zooplankton Production Symposium (May 2016; Bergen, Norway): Session 1. Application of optical and acoustical methods in zooplankton studies; Session 2. Response of zooplankton communities to changing ocean climate; Session 4. Zooplankton diversity in the oceans by integrative morphological and molecular techniques, Workshop 2. ICES PICES cooperative research initiative - towards a global measurement of zooplankton production; Workshop 4. Effects of microplastics on zooplankton; Workshop 6. A hands-on introduction to time series analysis, visualization, and inter-comparison of plankton survey data; and Workshop 7. Toward a taxonomically-comprehensive global reference database for DNA barcodes of marine zooplankton.
- DNA barcode sequences for invasive and non-indigenous species were added to the AquaNIS website by WGITMO/WGBOSV (ToR f).
- WGIMT members published papers in the peer-reviewed scientific literature on topics central to the WGIMT mission, exceeding our goal of 2 papers per year (ToR g), with 6 papers in 2013, 6 papers in 2014, 5 papers in 2015, and 7 papers in 2016.
- WGIMT members published a review article on integrative taxonomic approaches to characterizing zooplankton biodiversity in the peer-reviewed scientific literature (ToR g): Bucklin, A., P.K. Lindeque, N. Rodriguez-Ezpeleta, A. Albaina, and M. Lehtiniemi (2016) Metabarcoding of marine zooplankton:

Progress, prospects and pitfalls. J. Plankton Res. HORIZONS doi:10.1093/plankt/fbw023.

7) Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.

   WGIMT has sought direct contributions toward meeting ICES Advisory needs, including through direct cooperation with ACOM EGs. After failing to identify clear pathways of cooperation with ACOM EGs, WGIMT has focused on effective cooperation among SCICOM EGs, with the goal of facilitating and supporting direct cooperation forged by the respective chairs of SCICOM and ACOM.

8) Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.

   N/A

9) Please indicate what difficulties, if any, have been encountered in achieving the workplan.

   WGIMT sought joint ToRs with several SCICOM EGs, including WGBOSV and WGITMO (accepted for 2015; ended by joint agreement 2016) and WGAGFM (agreed delay until 2017). The difficulties are primarily due to lack of resources to support WGIMT's direct engagement with these groups.

Future plans

10) Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)

    WGIMT has shown significant success in working toward our goals and associated multi-annual 2014–2016 ToRs. Both membership and meeting participation has grown steadily throughout this period. Importantly, the group sees a clear way forward toward further promotion of our scientific goals in support of the ICES Strategic Plan (see #5, above) and also anticipates implementation of our advisory goals through practical applications in ecosystem assessment and fisheries management. WGIMT future plans include targeted contribution toward these additional elements of the ICES Strategic Plan:

    Science Plan Priority 3. Quantify the different effects of climate change on regional ecosystems and develop species and habitat vulnerability assessments for key species.

    The integrative taxonomic and metagenetic approaches promoted by WGIMT are appropriate and useful for analysis of responses of key species to climate change, including changes in population connectivity, distributional range shifts, local extinctions, etc.

    Science Plan Priority 4. Understand the influence of climate impacts across a range of temporal and spatial scales, from local to global and from seasonal to multidecadal and identify indicators of climate driven biotic responses and forecast trajectories of change.

The integrative taxonomic and metagenetic approaches promoted by WGIMT are appropriate and useful analysis of collections from time-series stations and monitoring surveys across a range of temporal and spatial scales.

Science Plan Priority 5. Quantify the role of structural and functional diversity in marine ecosystems in providing stability and resilience.

The integrative taxonomic and metagenetic approaches promoted by WGIMT can provide the fundamental information on structural diversity of the marine pelagic assemblage across different levels including populations, species (OTUs), and higher taxonomic levels.

Science Plan Priority 8. Define and quantify north Atlantic Ecosystem Goods and Services, model their dependence on ecosystem processes and habitat condition and their social, economic and cultural value.

Biodiversity is a fundamental property and essential and necessary contributor to ecosystem goods and services. As such WGIMT integrative taxonomic metagenetic / metagenomic approaches could contribute toward this priority.

Science Plan Priority 20. Provide priorities and specifications for data collection frameworks supporting IEAs.

WGIMT plans to work toward development of standardized metagenetic protocols for assessment of pelagic biodiversity in fisheries and ecosystem monitoring, time-series collections, and other programs and projects that require timely analysis of species-level diversity.

11) If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.

N/A

(*If you answered YES to question 10 or 11, it is expected that a new Category 2 draft resolution will be submitted through the relevant SSG Chair or Secretariat*.)

12) What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

N/A

13) Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)

WGIMT's future plans (see #10 above) include specific contributions to specific Science Plan Priorities that support the ICES Advisory process. In particular, WGIMT integrative taxonomic metagenetic / metagenomic approaches can contribute toward defining and quantifying North Atlantic Ecosystem Goods and Services (Science Plan Priority 8). WGIMT plans to work toward development of standardized metagenetic protocols for assessment of pelagic biodiversity can help provide priorities and specifications for data collection frameworks supporting IEA's (Science Plan Priority 20).