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Report of the Study Group on Integrated Morphological and Molecular Taxonomy (SGIMT)

by correspondence



ICES

International Council for
the Exploration of the Sea

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Executive summary

Since its inception by the WGZE and set up at the ASC in 2009, this small study group has been finding its way in a complex area over the past months. There have been a number of discussions between concerned scientists and at Expert Group meetings. While recognising that the ToRs for this study group represent the breadth of interest and endeavour required, they obviously add up to an impossible workload for the group in the time available in this year. Although these ToRs are considered in this report it is recognised that very much remains to be done to properly address them. The SG's initial efforts have focussed on exploring the territory and associated needs and resources.

In order first to determine the degree of interest and need for taxonomy in ICES, an introductory note and simple questionnaire (see Annex 4) was posted and posed to a set of 66 individuals chairing or representing ICES Expert groups. Responses were received from 26 Expert Groups and from some 27 other individuals representing their own and/or their institute and project interests. These have been appended to this report (Annex 4) and inform the SGIMT report as set out here. The SGIMT wish to express their thanks to ICES Secretariat for assistance and especially to all who responded to the questionnaire. The main significant issues highlighted by the questionnaire are summarised as follows:

- 1) There is consensus among responders on the fundamental requirement for taxonomic expertise, needed either directly or indirectly in their work. Examples include Species ID in the time series of plankton, benthos and fisheries surveys, for validating acoustics estimates, in studies of food webs and trophic interactions, biodiversity, contaminant effects, bioassays, parasitology, and many more.
- 2) Across the breadth of ICES expert groups, scientists are working with a huge range of marine organisms from microplankton through benthos, fish and marine mammals and birds, and in many environments and studies.
- 3) New policy demands and directives (Ecosystem Approaches, MSFD/GES descriptors, assessments and ICZM spatial plans etc.) are increasing demand for taxonomic expertise, while also requiring an increased diversity in species to be surveyed /studied and in the degree of integration between science disciplines doing so.
- 4) Data integrity is at risk if standards of taxonomic identification and nomenclature are not set and maintained. There are international projects developing these data and standards.
- 5) Nomenclature standards and taxonomic resources such as species keys and ID guides are not readily available to all, and/or they do not cover the extended regions and ranges of species that modern surveys and research require. Descriptions of less common species and developmental stages are often lacking or unavailable, at times impossible without molecular genetics.
- 6) Molecular methods are developing fast and widely appreciated as key to solving problems in species ID and to providing many new insights into such dynamics as trophic interactions, speciation and meta-populations, also in understanding of species relationships with their environments and reactions to stresses. However many molecular scientists and many field

ecologists have difficulties in establishing collaborative studies. Cost is an issue as is consistency over time in the rapidly advancing molecular methods and approaches.

- 7) Training and knowledge transfer are seen as key to expanding taxonomic expertise, resources and availability. True taxonomists are very scarce. Most ecologists and technicians that are actually identifying species and counting samples have little or no depth to their knowledge of taxonomy, beyond that required to ID and count organisms in those samples. Even these skills are often scarce, hard to learn and undervalued, requiring access to appropriate identification guides and keys, expert mentoring and considerable practical experience.
- 8) Many within and outwith ICES Expert Groups have said they are willing to help ICES and SGIMT address these problems and issues.

Taxonomy is critical to any national and international efforts that adopt ecosystem approaches to assessment and management of ecosystems, ecosystem services and species diversity and impacts on these. Such efforts must be achieved against a background of global development and changes in demography, climate and economics. Marine scientists in ICES expert groups are involved in marine surveys, monitoring and research on all marine phyla from microbes to whales and from coastal waters to deep seas. There is international acknowledgement of the decline and increasing need for taxonomic science, and for initiatives to fund developments and training for a new generation of scientists; with these fundamental skills and knowledge enhanced by modern developments in molecular chemistry and genetics. ICES can help to facilitate such developments through its access to knowledge in expert groups and through its advisory role.

New policies and pressures have arisen from science consensus and political necessities: Pressures include fishing, aquaculture, extraction of energy or aggregates, contaminants effects, climate change, acidification, species shifts and introductions, etc. Ecosystem approaches are now policy imperatives and the need is growing for indicators and assessments of good environmental status, for understanding of food webs and species adaptation, to preserve biodiversity or to minimise impacts on key communities and species, critical habitats, endangered species, etc. All of these need increased and inclusive taxonomic expertise, often additional to the science required in traditional studies and surveys of contaminant impacts and harvested stocks.

Different species react to and are affected by pressures in different ways. Introduced species, changes in community structure and in species phenology and productivity will affect food webs, trophic relationships, and the transfer cycles of nutrients, chemical elements, energy and biological production. If taxonomic skills and training are allowed to decline, then the capability to observe and discriminate sensitivities and effects on ecosystems and food webs will be badly compromised.

Several efforts to integrate and standardise taxonomic nomenclature and expertise are underway (e.g. GBIF, CoL, EoL, Species2000, WoRMS, ERMS, ITIS, EDIT, PESI and ETI). Several of these initiatives are time limited projects but outputs will be preserved and built on, through experts and data centres retaining e-infrastructures, tools and database outputs and through future projects arising from policy imperatives and expert networking. Some ICES experts and their colleagues are involved in these projects and ICES has experts active in taxonomic or taxonomy dependant research. For ICES managers and experts the question is; 'how to access these networks and databases to standardise services and add value to ICES products and advice?'

Getting taxonomy right is also a major concern for data management, in that confusion and errors in correctly naming taxonomic groups and species seriously degrades standards and data quality; while making compilation and comparisons difficult. **It is imperative that ICES nations and data managers have access to, and use, the most up to date and standardised taxonomic nomenclature.**

ICES should request species lists from expert groups, notably the WGPME, WGHABD, WGZE, BEWG, WGFE and WGBIODIV, these lists should be compared / checked against WoRMS to provide standard nomenclature and accepted synonyms using the new tool (<http://www.marinespecies.org/aphia.php?p=match>).

These same expert confirmed lists and standards should also be used to standardise nomenclature across ICES data holdings and products.

It is not always possible to determine taxa to species level due to practical limitations and logistics of sampling, analysis or available expertise and facilities. Often observations are of groupings at higher taxonomic levels or employ “common” names. These too can lead to confusions and incompatibility between datasets or in data comparisons. **It is important that projects and surveys standardise and include their choices of species ID levels in metadata relating to each study. Access through ICES data centre to recommended nomenclature, existing standards or previously used and corrected “species” lists would be a useful resource for ICES and other scientists.**

New molecular methods have already yielded new insights and have enormous potential. Taxonomy and phylogeny will be greatly revised, with new ways to ID species, assess abundances and gain insights into evolution, speciation, cryptic species and species adaptive capacities. Alongside this the study of genomics, metabolomics and gene expression etc., will provide direct insights for understanding relationships between species’ physiology, functions, meta/population dynamics and responses to environmental variations and stresses. Traditional taxonomy based on morphology has not been replaced though. Recent global studies such as CoML, BoL and others have emphasised the use and need for integrated taxonomy; for example by developing species genetic barcodes based on voucher specimens identified by expert morphological taxonomists. However, many marine species are not yet described, neither are the developmental stages of very many species, even common ones, which stages are indistinguishable from adults by molecular genetics. Many molecular methods are costly as yet, though rapidly becoming cheaper, and often molecular labs are focussed on more commercial applications and methods development. Specialisation can also be a problem, where for example a geneticist does not read or publish in the same journals as a fisheries or plankton ecologist, inhibiting understanding, collaboration and generation of new ideas, solutions and approaches.

It is apparent from discussion and the questionnaire that while many marine ecologists recognise the power of molecular approaches, many, if not most, have difficulty accessing the new methods. In contrast, many molecular biologists are marooned in labs, often without much access to broader problems and sampling opportunities that collaboration would provide. **ICES should act as communications link and facilitator, bringing the different morphology and molecular based taxonomic experts together with ecologists, fisheries scientists etc., while highlighting identified issues and problems to scientists, policy makers and funders.**

To this end the SGIMT would work with ICES web manager and expert groups to deliver pages related to the science of taxonomy; including news of developments,

current issues, meetings, training, workshops etc., and providing or linking to knowledge, resources, research initiatives and expertise on line or in the literature.

1 Opening of the meeting

The SGIMT was established and worked by correspondence in 2010.

2 Agenda

The working agenda was simply to discuss the ToRs, compose and send out the questionnaire and seek comment on responses and the ToRs; then to summarise these for this report.

- a) Identify resources, current gaps, and important issues in taxonomic research;
- b) Provide a platform for promotion and exchange of relevant scientific information;
- c) Initiate and support provision of standards, training materials, and taxonomy workshops;
- d) Assist in the revision and development of species identification keys;
- e) Develop the continuing integration of molecular and morphological taxonomy;
- f) Advise on the implications of developments for marine science and management.
- g) Provide recommendations on approaches for the effective and broad dissemination of knowledge developed by the expert group, including estimates of resource requirements;
- h) Report by 15 March on potential contributions to the high priority topics of ICES Science Plan by completing the document named "SSGEF_workplan.doc" on the SharePoint site. Consider your current expertise and rank the contributions by High, Low or Medium importance;
- i) Prepare contributions for the 2010 SSGEF session during the ASC on the topic areas of the Science Plan which cover: Individual, population and community level growth, feeding and reproduction; the quality of habitats and the threats to them; indicators of ecosystem health.

Annex 1: List of participants

Name	Address	Phone/Fax	Email
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Many Other Experts who aided in discussion and through responses to the Questionnaire.			

Annex 2: SGIMT draft Terms of Reference for the next meeting

The **Study Group on Integrated Morphological and Molecular Taxonomy (SGIMT)**, chaired by Steve Hay, UK, will meet by correspondence in 2011 to:

- a) Identify resources, current gaps, and important issues in taxonomic research;
- b) Develop a web platform for promotion and exchange of relevant scientific information;
- c) Initiate and support provision of standards, training materials, and taxonomy workshops;
- d) Assist in the revision and development of species identification keys;
- e) Develop the continuing integration of molecular and morphological taxonomy;
- f) Advise on the implications of developments for marine science and management.

SGIMT will report by 15 June 2011 (via SSGEF) for the attention of SCICOM and WGZE.

Supporting Information

Priority:	The activities of this Group will assist ICES and its expert groups with issues related to the development, dissemination and application of taxonomic knowledge and skills. These skills underpin much of the work of ICES and ICES expert marine scientists, and policy demands are driving increased need for taxonomy in ecosystem approaches, effects of fisheries and contaminants, development and application of GES indicators, climate change issues etc. The growing need for taxonomy, with its new developments and methods, with problems of dispersed knowledge, scarce expertise and data quality issues; these make the study group's activities important and high priority.
Scientific justification and relation to action plan:	<p>Taxonomy as a fundamental discipline in general and evolutionary biology, ecology and environmental management. As such, this discipline is critical to successful understanding, assessment and management of the species diversity and relationships in undisturbed ecosystems and in those affected by natural or human activities such as climate change/ acidification, industrial pressures or eutrophication. There are globally increasing demands on this science. There are also many efforts to reverse the decline in marine taxonomic expertise and to advance traditional morphology-based phylogenies into the new frontiers opened up by molecular genetics. WGZE has sponsored and arranged plankton taxonomic workshops and has strong associations with several of these global initiatives. Taxonomic experts are relatively few in many but not all ICES nations and they tend to specialise in certain taxa rather than generally across the diversity of plankton species.</p> <p>ICES major role is in the collation, archiving, and dissemination of scientific data, analyses and evidence based advice to support policy making, regulatory control. These activities support the conservation and sustainable use of marine resources and ecosystems and ICES facilitates international collaborative science to achieve these aims. ICES has critical supporting and training roles in global marine science, through promoting scientific standards, new research and developments and training opportunities. Taxonomic standards and descriptions are subject to constant change and development. Particularly, taxonomy grows with new molecular approaches to species phylogeny, evolution, species adaptive capacities, environmental sensitivities and community diversity. These are highly significant new developments that in a</p>

	<p>few years will have revolutionised the monitoring and study of marine species and ecosystems. It is essential that ICES adopts a positive supporting role in assessing taxonomic methods, information and potential new techniques by coordinating and promoting developments and information feed-back to the scientific community who support ICES data provision, analyses, and advice. Considering the plethora of internet and other developments in taxonomic information, ICES should develop its own web served taxonomic information. Many existing efforts are short-term funded and evolve through multiple short term efforts. Even major programs such as CoML/CMarZ or the EU MARBEF, EDIT, GBIF, PESI networks) have limited lifespans. ICES has a role in conserving and developing the gains they have made and disseminating the results to ICES scientists and their colleagues. Collectively and specifically these global efforts on traditional and molecular taxonomy amount to a valuable and developing resource. ICES as a stable, long lived and international institution has a major role to play in the collation, review, and application of these efforts, in promoting best practices and standards while coordinating development and dissemination of such information.</p>
Resource requirements:	<p>The research programmes and expert group activities which provide input and are stakeholders for this group are already in place. The additional resource required by SGIMT to pursue activities are negligible. The exception is that is some time of ICES web master would be needed to help SGIMT set up a web presence holding taxonomic information and links.</p>
Participants:	<p>The Study Group has a limited membership at present but in the near future aims to include scientists with appropriate skills that have expressed interest in its work from other ICES Expert groups and elsewhere.</p>
Secretariat facilities:	<p>None.</p>
Financial:	<p>No financial implications.</p>
Linkages to advisory committees:	<p>There are no direct linkages with the advisory committees.</p>
Linkages to other committees or groups:	<p>The Study Group arose from the WGZE as a response to a perceived need. This was to promote and support morphological and molecular taxonomy science for the benefit of many ICES Expert groups and marine science generally.</p>
Linkages to other organizations:	<p>The work of this group relates to and is connected to a diversity of other projects and organisations, such as EU projects like PESI and the US led Census of Marine Life Programme and many others.</p>

Annex 3: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. It is imperative that ICES nations and data managers have access to, and use, the most up to date and standardised taxonomic nomenclature. Expert-confirmed lists and standards should also be used to standardise nomenclature across ICES data holdings and products. Access through ICES data centre and web site to recommended nomenclature, existing standards or previously used and corrected “species” lists would be a useful resource for ICES and other scientists.	ICES Data Centre
2. ICES should request regional species lists from expert groups, notably the WGPME, WGHABD, WGZE, BEWG, WGFE and WGBIODIV, these lists should be compared / checked against WoRMS to provide standard nomenclature and synonyms using the new tool (http://www.marinespecies.org/aphia.php?p=match).	WGPME, WGHABD, WGZE, BEWG, WGFE and WGBIODIV
3. It is important that ICES projects and surveys standardise and include their choices of species ID levels in metadata relating to each study.	Generally addressed to ICES
4. ICES should act as communications link and facilitator, bringing the different morphology and molecular based taxonomic experts together with ecologists, fisheries scientists etc., while highlighting identified issues and problems to scientists, policy makers and funders.	Generally addressed to ICES
5. SGIMT would work with ICES web manager and expert groups to deliver pages related to the science of taxonomy; including news of developments, current issues, meetings, training, workshops etc., and providing or linking to knowledge, resources, research initiatives and expertise on line or in the literature.	Generally addressed to ICES

Annex 4: Questionnaire Responses

Question 1. Do you consider a sound understanding of taxonomy critical to your work?

Responses by ICES Expert Groups:

(WGPME, WKREDS, WGCAN, WGNAPES, WGFE, WGZE, SGCC, SSICC, WGZE, WGIPS, WGFAS, WGCEPH, WGBEAM, WGNEW, WGCSE, WGDIM, IBTSWG, BEWG, WGEXT, WGBIODIV, WGHABD, WKANSARNS, WGOOFE, WGRS, IGWG, IBTSWG.)

Virtually all of the chairs or members of the above 26 expert groups that responded, considered taxonomy critical to their work. For many it was a fundamental and direct use of taxonomic expertise and resources, while others recognised that they depended more indirectly on taxonomic expertise for ensuring the quality of sampling, analysis and data integrity in their work or models. This was also true of the 22 individuals or organisation representatives that responded. There were some that could not see any particular requirement for taxonomic expertise in their work and had no such skills to offer, but recognised that many other scientists, including work colleagues very much depended on taxonomic expertise.

Comments on Question 1:

Helgoland hosts one of the most detailed taxonomic data series for phytoplankton in Europe and taxonomic expertise is required for instance to give advice on the level of ID possible for certain taxon groups and the evaluation of 'new records', of which there have been many recently.

Issues relate to less common, often improperly identified species. Our focus being biodiversity and species at risk

I myself work on morphological taxonomy of calanoid from the deep sea. Furthermore we manage a German zooplankton time series. The knowledge on taxonomy is crucial for this work to investigate biodiversity and changes within, e.g. related to climate forcing.

Otherwise our acoustics data cannot be used to characterise micronekton layers or nektonic organisms.

As chief scientist of both Belgian fishery surveys, I often get confronted with different name-giving to the same species of fish by different scientists (set aside the names that the observers and fishermen use). Sometimes, also different databases where the data need to be uploaded use different names. This creates a lot of confusion, and could potentially lead to important mistakes.

Many species may respond differently to human impacts like aggregate extraction.

Taxonomy and systematics are fundamental to biodiversity science, and good taxonomic knowledge and field identifications are fundamental if species-site data sets are to be used for examining spatial and temporal patterns in species diversity.

I consider it is a key issue in our work in bottom trawl surveys, not so much from the point of view of the commercial species, which usually are well known and relatively easy to identify, but especially in relation to the accompanying species, which are getting more and more attention when considering the Ecosystem approach and the biodiversity studies.

My primary duty is to conduct taxonomic research and apply the results to our assessment surveys. Our work has revealed, recognized, and described cryptic species of commercial fisheries significance and has described new species of fishes encountered as bycatch.

Personally I do not need to be able to identify organisms but rely on others to do so.

I talked to my colleague about your e-mail, but we felt that it was a bit remote from our area of work, so we doubt that we can contribute much of relevance. However, it is an interesting area and I hope that you will receive enough information to go on with the work.

Sound understanding of taxonomy is critical for our molecular work. We cooperate with the national history museum in the Netherlands (NATURALIS) for taxonomical expertise.

Understanding taxonomy is key to consistent and accurate identification of early life stages of marine fish.

We investigate processes of speciation, so sound taxonomic identification of individuals and groups is critical.

Question 2. Which species groups does your work require knowledge of?

Responses by ICES Expert Groups:

WGPM - Dinoflagellates, diatoms, General knowledge: ciliates, coccolithophores, small flagellate taxa, Additional expertise that would be useful; radiolarians have been very abundant this year.

WKREDS - Atlantic redfish (*Sebastes* spp.)

WGRS - Primarily redfish species (Sebastes) in the North Atlantic (*S. mentella*, *S. marinus*, *S. vivparus*, *S. fasciatus* and potentially other *Sebastes* species) as well as a number of groups caught as bycatches during the surveys (commercial fishes: herring, blue whiting, cod, haddock, etc, myctophids and other mesopelagic fishes, shrimps, krill, cephalopods, jellyfish).

WGCRAN - crangonids

WGNAPES - Small pelagics and mesopelagic species found from the NE Atlantic.

- All species of fish and macrozoobenthos (the by-catch of the demersal trawl during the autumn ecosystem survey) of the Barents Sea.

WGFE - Marine fish (WGFE) Marine species in general (Can. Taxonomy WG)

WGZE - All phytoplankton, zooplankton and micronekton species of the NW Atlantic and Arctic.

- Mainly copepods and fish larvae, but we try to identify at species level any planktonic item.

- Calanoid copepods, North Sea zooplankton in general.

- For experimental work we mostly require knowledge of Calanoid copepods and meroplankton (decapod and bivalve larvae).

- For long term time series analysis: Protozoa, Cnidaria, Nematode, Platyhelminthes, Ctenophora, Polychaeta, Chaetognatha, Phoronida, Bryozoa, Nemertina, Mollusca, Echinodermata, Hermichordata, Urochordata, Chordata, Crustacea Cirripedia, Cladocera, Ostracoda, Isopoda, Amphipoda, Cumacea, Mysidacea, Euphausiacea, Decapoda, Copepoda Calanoida, Copepoda Cyclopoida, Copepoda Harpacticoida, Copepoda Siphonostomata, Copepoda Monstrilloida, Chelicerata.

- I am analysing ichthyoplankton but as I am mostly interested in trophic interactions between ichthyoplankton and zooplankton, the expertise within my group in zooplankton taxonomy is crucial for me as well.

- Copepods, Ciliates, Polychaetes, Molluscs.

WGFAST - Most common micronekton in tropical/subtropical waters; tuna species in the Pacific, bottom fish species actively fished in the Pacific.

WGCEPH - Cephalopoda

WGBEAM / WGNEW / WGCSE - Anything that can turn up in bottom trawl catches, so fish, shellfish, crustaceans, cephalopods.

- Fish, macro-epifauna (e.g. Crustaceans, Cephalopods, Molluscs)

WGEXT - Macrobenthos, epibenthos, bottom-dwelling and demersal fish

BEWG - Polychaeta, Crustacea (mainly; Brachyura, Anomura, Amphipoda and Cumacea), Bivalvia and Echinodermata.

WGBIODIV - All, but primarily benthic invertebrates and fish at the moment (most WG participants are involved in the collection and interpretation of data for these groups). However the remit of the WG would allow all marine taxa occurring in the iceas area to be addressed.

WGHABD - Particularly interested in the occurrence, distribution and of the dynamics of harmful micro algal species, which are known in all phytoplankton groups including dinoflagellate, cyanobacteria and diatoms.

WKANSARNS - Zooplankton, phytoplankton, fish (ichthyoplankton), clupeid fish at all life stages.

WGOOFE - Zooplankton, phytoplankton, fish (ichthyoplankton).

IBTSWG - All marine macrofauna, especially fish, elasmobranches, crustaceans, cephalopods, and other invertebrate groups

IGWG - NOAA - Everything sounds too broad, but in the spirit of GOOS it is appropriate.

Others' Responses:

- Plankton and nekton (especially fishes) mainly but, potentially, all marine organisms

- Primarily, taxonomy of fishes of the North Pacific Ocean. My group also requires a familiarity with the taxonomy of demersal invertebrates encountered in our surveys.

- We work on any marine species, our work ranges from bacteria up to mammals.

- We have setup a web-based database with methods to identify marine teleost species using taxonomical and molecular features (www.fishtrace.org). At this

moment I have started to develop methods for the identification of all marine benthic species in one environmental sample using the next generation sequence technology (community fingerprinting).

- The larval stages of marine fish from the east coast of the United States and the Gulf of Mexico

- I work with larval fishes. My past work has focussed on Anguilliform fishes and pelagic. However some of the questions I have previously addressed have required identifying eggs in subtropical waters. This requires a very broad level of knowledge of teleost fishes.

- Cephalopods (squid, cuttlefish and octopus), fish (marine and freshwater), crustaceans (crab), gastropods (limpets) and bivalves (cockles)

- Different groups of parasites (myxosporea, helminths, copepoda) of the North Atlantic and Barents Sea fishes, except for parasites of blood.

Question 3. Does your work require or employ expertise in taxonomy through molecular genetics?

Responses by ICES Expert Groups:

WGPME - involved in some studies on the ecological relevance of intraspecific diversity in the diatom *Thalassiosira rotula* and this work will continue.

WKREDS - Yes, see WKREDS 2009 report.

WGCRAN - No

WGNAPES - Not as yet.

- It is required sometimes (not always), but we don't employ it.

WGFE - not directly but Can Tax WG at DFO does, examples include species at risk, usually at the sub-species level.

WGZE -

- No. There are certain species that do require it in our region (e.g. *Pseudocalanus* spp. and the naupliar stages of the three common *Calanus* spp.), but we do not have the ability (funds, expertise) to do it.

- We do not have expertise.

- Yes, specifically in case of morphologically similar species of the same genus (e.g. *Pseudocalanus*), cryptic speciation etc. Also, there are long term initiatives in our institute for the development of fast identification of organisms/specific groups/genera in bulk zooplankton samples by new molecular genetics methods.

- Yes our work requires and employs expertise in taxonomy through molecular genetics. P. Lindeque has been working for 15 years using molecular techniques to look at the systematics, development and trophic interaction of zoo-plankton. She has developed molecular techniques to identify between the four *Calanus* congeners in the North Atlantic, undertaken phylogenetic re-search and merged conventional microscopy and molecular techniques to identify *Calanus* species in the large field surveys of Marine productivity.

- Not so far, but it seems to be of increasing importance recently, especially regarding jelly samples

- Yes, my work requires molecular techniques but unfortunately does not employ taxonomy through molecular genetics

WGFAST - No

WGCEPH - I'm not work using molecular genetics, but I collaborate in interdisciplinary research that use molecular genetics.

WGBEAM (WGNEW, WGCSE, WGBEAM, WGDIM, IBTSWG, BEWG) - Not much, but it happens. In my case, I am also working on turbot and brill in the ICES-group WGNEW. Ultimately (but we're not there yet) this should lead to stock assessments for these species in areas where no analytical assessments exist yet. As a basis for stock description, we have a PhD-student working on the genetic structure of both species all over their European ranges, in collaboration with the University of Leuven (where the molecular work is being performed).

- Requirement: not yet? Employment: no

WGEXT - Not directly, but might help if analyses could be made easier/faster.

BEWG - No

WGBIODIV - Partly. There is clearly a role for molecular genetics to help inform and support traditional (morphological) approaches for higher taxa and to underpin studies on microbial taxa.

WGHABD - There are no requirements however, it is very useful to discriminate otherwise difficult phytoplankton species and this has recently been incorporated in the HAB monitoring programmes in several countries.

WKANSARNS - Yes

WGOOFE - Yes

WGRS - Partly. This has been done to investigate *S. mentella* population structure in the Irminger Sea and is ongoing in the Norwegian/Barents Sea.

IGWG - NOAA - We have started using molecular genetics.

IBTSWG - Not directly, since one of the problems in surveys is getting a good and quick identification in the field, so improvements in field taxonomy are one of our needs in bottom trawl surveys, and validation of the taxonomy performed on board and producing ID keys with this scope are one of the issues that would be required from molecular genetics.

Others' Responses:

- Yes

- Yes. Our work employs molecular genetics to assist in identifying new or poorly known species of fishes, as well as in erecting phylogenetic hypotheses. We collaborate with personnel at molecular genetic labs in our center or at academic institutions.

- Yes

- Yes, our work requires and employs expertise in taxonomy through molecular genetics. P. Lindeque has been working at PML for 15 years using molecular techniques to look at the systematics, development and trophic interaction of zooplankton. She has developed molecular techniques to identify the four *Calanus* congeners in the North Atlantic, undertaken phylogenetic research and merged conventional microscopy and molecular techniques to identify *Calanus* species in large field surveys of Marine productivity.

- Yes our work employs expertise through molecular genetics.

- Yes. I've been involved in projects where larval fish specimens were genetically identified and examined morphologically. The aim of these projects was to determine whether morphological traits could be identified to improve morphological identification of species using genetically identified knowns.

- Yes. Molecular identification of larval fishes was an integral component of my dissertation research. The questions I addressed could not have been answered without the molecular identification of larval fishes.

- Yes - I run a molecular ecology laboratory where we use genetic techniques spanning individual (individual and species ID, fingerprinting), population (population structure and ID of mixed stocks), and phylogenetic (systematics, phylogeography) level analyses. I have investigated using genetic methods to ID and track planktonic larvae.

- No

Question 4. Do you support the need for taxonomic research, training and knowledge transfer?

Responses by ICES Expert Groups:

WGPME - Yes, wholeheartedly. In the phytoplankton groups we work with, there are many very large families with dozens or even hundreds of species that often contain very similar species. This causes a lot of ID errors unless analysts have the knowledge to decide for which reliable identifications are possible and for which taxa they are not. However, this requires at least some basic training on the diagnostic characters of different taxon groups (even if they are not always visible particularly in Lugols fixed samples), so that informed and consistent decisions can be made during routine counting.

WKREDS - Yes.

- Yes. See recent review by Boero (2010): The Study of Species in the Era of Biodiversity: A Tale of Stupidity. [Diversity 2010, 2, 115-126; doi:10.3390/d2010115].

- Definitely!

Looking only at the problems of identifying and classifying redfish *Sebastes mentella* in the North Atlantic. There is a strong need for the mentioned research, training and knowledge transfer.

WGRS - Yes in principle, in particular strong expertise in the differentiation of redfish species, but also for exhaustive identification of by-catch species. In practice, however, the WGRS group does not currently act to support such activities.

WGCRAN - Yes

WGNAPES - Yes

WGFE - Yes, in its absence, problems have arisen.

WGZE - We do very little (e.g. occasional participation in Workshops, such as those run by SAHFOS), but we strongly support the need for taxonomic research, training, and knowledge transfer in principle. Our "operational taxonomists" have developed most of their taxonomic knowledge "on the job", but they are very competent.

- Of course. Training courses and workshops in our institute (for students, technicians as well as scientists) are regularly given. Furthermore and we cooperate with a series of international experts of different marine groups of organisms (both, benthos and zoo-plankton, e.g. amphipods, isopods, polychaetes, chaetognaths, calanoid copepods, harpacticoid copepods).

- Yes, we have worked hard to employ a junior member of staff to be trained in zooplankton taxonomy while the expertise for training is still available.

- Absolutely!

- Yes

- (+ SGCC, SSICC) - We would like to teach young student, but young people is more inclined to use semi-automatic techniques

WGFAST - Yes

WGCEPH - Yes

WGBEAM - Absolutely!! I don't think the (Belgian) research group I am involved in should take up taxonomic research itself, but training and knowledge transfer is becoming more important by the day, especially now we're moving towards an ecosystem approach for fishery management. Two years ago we started identifying all species on surveys, and this year we started taking up the concurrent sampling on observer trips (so a larger set of fish species are being identified and documented by the observers, whereas previously they mainly focused on the most important commercial species).

- WGNEW - Yes

- WGCSE - Yes

- WGDIM - Yes

- IBTSWG - Yes

WGEXT - Yes, it is still the basic for all ecological research.

BEWG - Yes

WGBIODIV - Yes. Taxonomy and systematics are very important. In terms of field expertise, access to up-to-date, user-friendly and accurate identification keys is important, and such guides are not available to all taxa/sea areas.

WGHABD - Yes

WKANSARNS - Yes

WGOOFE - Yes

IGWG - Yes

Others' Responses:

- Yes

- Absolutely. Taxonomic knowledge is critical to conduct ecosystem management. Within our working group, taxonomic research is ongoing and taxonomic knowledge is transferred to field biologists and researchers in other disciplines through training, seminars, and publication of research results.

- Yes I support that need. We cannot develop proper genetic assays for species identification without properly identified reference samples to start with.

- Yes, we have worked hard to employ a junior member of staff to be trained in zooplankton taxonomy while the expertise for training is still available.

- Yes

- Yes

- Yes. We have found that molecular work can be an essential component of developing morphological identification techniques. By doing these studies, archived samples can be identified and the molecular identification work can be targeted at the most important samples. An additional problem I have run into is when the molecular work clearly points to the existence of cryptic species. Taxonomic expertise to clearly address these issues is often hard to find.

- Yes

- Yes

Question 5. Can you identify problems, knowledge gaps or issues we might address?

Responses by ICES Expert Groups:

WGPME - similar to Q4: One important issue would be to place taxonomic issues in a more practical context for analysts involved in regular monitoring activities. Many analysts have no real taxonomic knowledge but can still carry out reproducible counts. For Lugols fixed samples, many truly diagnostic features are not visible, different characteristics are often used to differentiate between species, sometimes species names are also assigned to a species on the basis that they 'usually' occur during a given period. A better grounding in at least basic taxonomic issues and the relationships between different taxon groups could support their difficult task and increase the taxonomic resolution of a data series (has to be done carefully of course to avoid artefacts in the data series). An example of a very successful course trying to achieve this is the 'advanced phytoplankton course' held biannually in Naples

WKREDS - Mixed species fishery and survey catches of *Sebastes*, as well as mixed-stock catches of *S. mentella*.

WKREDS - Identify problems with species identification in the field (surveys and commercial sampling at sea and fish markets), list relevant taxonomic groups and recommend practical solutions or further research.

WKREDS - There is a strong need for the mentioned research, training and knowledge transfer

WGCRAN - No answer

WGNAPES - Review of existing knowledge base and a renewed awareness of existing compiled literature would be useful.

WGNAPES - Autumn ecosystem survey in the Barents Sea is the Russian-Norwegian survey, so we need the identical determination of the same species by scientists of the both institutes. It is almost OK this fishes but this problem have not solved with the macrozoobenthos by-catch. It will be useful to calibrate species determinations of different institutes.

WGFE - Yes

WGZE - Yes, current initiatives often point towards new methods, e.g. optical methods, which are less time consuming than classical counting but can't not replace them in accuracy

WGZE (SGCC, SSICC) - How to make taxonomy attractive to the new generations

WGZE - Yes, no funding for the fundamental research of classic, morphologic taxonomy, loss of experts (a problem specifically connected to the latter), a general lack in the education of 'classic' taxonomic methods; more specifically: the quality in identification of organisms by different researchers/technicians/labs specialised is often not consistent. A comparability of different samples/ studies from the same area (e.g. North Sea) is hampered by this.

WGZE - A long-standing problem is the correct identification of difficult sibling copepod species, and many taxa in our time series analysis cannot be identified to a high taxonomic resolution due to time constraints on microscopy and lack of molecular tools. For example, uncertainty exists for the species complex *Pseudo-/Para-/Clauso-/Ctenocalanus*, especially for immature copepodites, but also for adults. Similar problems exist for *Calanus* spp. in other regions, and we occasionally encounter *C. finmarchicus* individuals in addition to the common *C. helgolandicus*, the former being easily overlooked. The correct distinction of these species becomes increasingly important with northward shifts of warm-adapted populations as a cause of climatic warming. Hardly any taxonomic information is available for copepod nauplii, despite their important ecological role in marine food webs. Many taxa are identified based on their presumed biogeographic affiliation (counted as what would be expected in a given location, e.g. *Pseudocalanus elongatus*, *Acartia* species?), rather than actual confirmation of species/taxon; this may give rise to misidentification of closely related invasives/new arrivals, especially with environmental changes. Some particularly difficult taxa for morphological identification are also meroplanktonic larvae such as cirripedes, decapods, bivalves, which are at times extremely abundant in the plankton and thus major players in the food webs at times. However, they are highly understudied, partly due to taxonomic difficulties.

WGZE - Taxonomic expertise is shrinking (not to say dying out) and we should do something with that! Trainings and kind of experts' networks should be organised

WGZE - I am working on fish larvae feeding and therefore I would like to be able to identify the food content in their stomachs. Being able to identify the species throughout molecular taxonomy would greatly improve my understanding of their diet, food preferences/availability and effect on growth.

WGIPS -

WGFAST - There is not much information available on most micronektonic species in tropical/subtropical waters.

WGCEPH - We need change the general idea (for most people, including researchers) that Taxonomy is a science for XIX century and not necessary in the science of XXI century.

WGBEAM - how to deal with species only distinguishable by molecular genetics when doing field work?

WGNEW

- WGCSE

- WGDIM

- IBTSWG

- BEWG

- BEWG - Collect and disseminate new and/or updated species identification literature/keys. Organize taxonomy workshops.

WGEXT - Consider answer to Q3

BEWG - Yes

WGBIODIV - Lack of taxonomic knowledge of some of the 'minor' taxa and smaller bodied organisms.

Lack of up-to-date, user-friendly and accurate identification keys/guides for some taxa/sea areas. 3. Certain sister taxa that may key out differently on the basis of their morphology can be highly variable, and it is genetic studies to determine whether such taxa are distinct or simply different growth forms are required

WGHABD - Some phytoplankton groups will need exploration into different parts of the genome (different from ribosomal DNA) for proper species identification (alternative markers). There is considerable research required in investigating variability in the genome among species from different biogeographical regions and how this relates to variability in toxin profile and content. Basic research requirement in the field of morphospecies versus genospecies: the species concept. Application of the sequence markers in enumeration and quantification of species (qPCR techniques automated high throughput of field samples)

WKANSARNS - Rapid automated ichthyoplankton identification, stomach contents ID

WGOOFE - Need rapid and automated methods for ID of fish and stomach contents

WGRS - Redfish species identification and population structure are critical issues in the North Atlantic. They have been addressed through a number of studies in the past and ICES working groups (WGSIMUR, WGREDS), but much remains to be done. In addition, the registration of mesopelagic fauna (down to 1000m) in the Irminger, Norwegian and Barents Seas suffers from lack of coordinated taxonomical expertise between countries, lack of exhaustive identification of collected specimens and a lack of common protocols for handling information on specimens that can not be identified onboard (photographs, frozen specimens, ...).

IGWG - Yes

IBTSWG - Yes, As mentioned above, from the bottom trawl surveys point of view, field taxonomy and validating the ID keys used on the surveys are something to address, together with the use of sound levels to maintain similar standards in time series studies and at the same time being able to improve the quality of the taxonomy

used along the time series, something important when considering biodiversity studies.

Others' Responses:

- Although important work has been done in molecular ID of fishes (e.g. Fish & Chips and Fishpoptrace programs) and many more is to come, few projects are being devoted to the rest of marine organisms; in this sense, I really miss the development of an integrated protocol, combining molecular, image analysis and classical (microscope) methods, for the ID of marine organisms worldwide. I think that investing time and resources in this field is of high concern and that taxonomists, molecular biologists and informatics among others should work together to be able to fill this gap. I think that the ICES SGIMT group would a nice opportunity to achieve this.

- I'm not clear about the specific purview of SGIMT, but in our region, the primary knowledge gap that affects our work is the lack of taxonomic knowledge of non-commercial demersal macroinvertebrates.

- Yes. We cannot develop proper genetic assays for species identification without properly identified reference samples to start with. We have had trouble getting samples suitable for DNA analysis from properly identified species.

- A long-standing problem is the correct identification of difficult sibling cope-pod species, and many taxa in our time series analysis cannot be identified to a high taxonomic resolution due to time constraints on microscopy and lack of molecular tools. For example, uncertainty exists for the species complex Pseudo-/Para-/Clauso-/Ctenocalanus, especially for immature copepodites, but also for adults. Similar problems exist for Calanus spp. in other regions, and we occasionally encounter *C. finmarchicus* individuals in addition to the common *C. helgolandicus*, the former being easily overlooked. The correct distinction of these species becomes increasingly important with northward shifts of warm-adapted populations as a cause of climatic warming. Hardly any taxonomic information is available for copepod nauplii, despite their important ecological role in marine food webs. Many taxa are identified based on their presumed biogeographic affiliation (counted as what would be expected in a given location, e.g. *Pseudocalanus elongatus*, *Acartia* species?), rather than actual confirmation of species/taxon; this may give rise to misidentification of closely related invasives/new arrivals, especially with environmental changes. Some particularly difficult taxa for morphological identification are also meroplanktonic larvae such as cirripedes, decapods, bivalves, which are at times extremely abundant in the plankton and thus major players in the food webs at times. However, they are highly understudied, partly due to taxonomic difficulties.

- My experience is, that is very difficult to introduce molecular techniques in regular marine monitoring. For example, I suggested to identify Clupeidae zooplankton with molecular techniques, since it is difficult to do so by taxonomical features. However, IMARES was not interested because everybody in Europe only uses taxonomical features. Developing molecular community fingerprinting methods for zooplankton in co-operation with taxonomists should be very worthwhile, but also in these cases

they stick only to taxonomical features. In several cases it is not possible to identify the species.

- Consistency of molecular methodologies over time - by the time a project is ready to publish (the time between collecting samples doing morphological and molecular analyses, and writing is sometimes years), the preferred methodology (e.g., bar-coding vs. RFLP or one gene vs. another) has changed. Consistency of molecular results - there seems to be those who believe genetic analyses are flawless, but things can and often do go wrong. Strict protocols to prevent contamination and ensure repeatability of results need to be followed and described in publications. There are thousands of fish species whose larval stages are not yet described. Many of these are commercially/recreationally important and/or threatened and understanding early life history processes or being able to use the fisheries independent data being collected in large scale sampling could greatly improve management.

- Our biggest need is for high-throughput cheap molecular identifications of fish eggs and larvae. This sort of capability would allow us to broaden the number of species that we are developing indices of abundance for from our plankton surveys. There are specific broader issues in the northeast U.S. such as the identification of sand lance to species at all life stages.

- Study of parasite fauna of the North Atlantic redfish (genus *Sebastes*) and other fishes and red king crab of the Barents Sea. Use of parasites for ecology, stock structure, population structure, migrations of their hosts. Study of fish parasites vs unhealthy people.

Question 6. Would you be willing to provide expertise to assist ICES, through SGIMT, in maintaining taxonomic expertise, its application and quality?

Responses by ICES Expert Groups:

WGPME - Yes

WKREDS - Yes - conditional on other commitments that may take priority

- WKREDS - Certainly our institute is willing to contribute

WGCRAN - if of use

WGNAPES - Yes, if required

- WGNAPES - Yes

WGFE - I can liaise with the Canadian initiative, provide some of their insight

WGZE - Yes

- WGZE (SGCC, SSICC) - Not in my current situation as I cannot fund myself for this kind of meetings

- WGZE - Yes. First plans to conduct regular ring experiments between German institutes on zoo-plankton identification are already made in cooperation with Maarten Boersma from the AWI in Germany to ensure the quality and comparability between different time series/monitoring stations in Germany. Also, different workshops, e.g. on taxonomy of calanoid and harpacticoid copepods as well as on barcoding were held at our institute during the last years and will be continued to be conducted.

- WGZE - Yes

- WGZE - Not personally, I am afraid. I am trying to convince our Sorting Centre in Szczecin to be involved somehow. I hope we will have opportunity to discuss those issues during our next WGZE meeting in Gdynia.

- WGZE - Yes, but only on morphological taxonomy since I don't have any sort of expertise in molecular taxonomy.

WGIPS - No response

WGFAST - not a taxonomic expert, not even a biologist, so I rely on others and published literature. I doubt I could provide any help/information on the subject

WGCEPH - If possible... yes. But I have a lot of work in the University and don't have time

WGBEAM - Although my taxonomical knowledge only originates from literature and the web (so I don't do any taxonomical research myself, but I am very much interested in taxonomy), I would be happy to assist ICES/SGIMT whenever this seems useful

- WGNEW - Yes

- WGCSE - Yes

- WGDIM - Yes

- IBTSWG - Yes personally, submitted to the rest of the members of the IBTSWG, participation has to be decided individually.

- BEWG - Yes

WGEXT - As an ecologist I only 'use' taxonomy to identify species. As such I am not really an expert in taxonomy. So it would mainly be in the 'application' field

WGBIODIV - Yes

WGHABD - Yes, WGHABD are willing to assist the study group in providing what expertise in taxonomy and molecular applications thereof that may be relevant. The ICES SGIMT should be aware that the IOC also has a high level objective to maintain taxonomic expertise in the field of HABs. This includes the IOC Taxonomic Reference for Toxic Phytoplankton which is an element of the World Register of Marine Organisms (WoRMS) at <http://www.marinespecies.org/hab/index.php> and an Intergovernmental Task Team on Harmful algal Taxonomy. The IOC HAB Programme, to which WGHABD is affiliated, has for the past 20 years conducted training in HAB taxonomy and species identification. Any further strengthening of these efforts in ICES context is supported and encouraged.

WKANSARNS - No, as membership does not have this expertise

WGOOFE - No, as membership does not have this expertise

WGRS - This is clearly not my field of expertise, so I see myself (and WGRS) mostly as receiving advice from SGIMT rather than actively contributing with taxonomic expertise to the group.

IGWG - Yes - or find people who can.

Others' Responses:

- Eight positive responses; along with the comments:
- Yes, to a limited extent.
- I would like to do so, on the introduction of molecular techniques together with taxonomists. Although my taxonomical knowledge only originates from literature and the web (so I don't do any taxonomical research myself, but I am very much interested in taxonomy),
- Not really qualified - I use taxonomic expertise (and work on the fringes of molecular taxonomy) but do not really consider myself an expert in its practice or teaching.