ICES WGTC REPORT 2014

SCICOM STEERING GROUP ON ECOSYSTEM SURVEYS SCIENCE AND TECHNOLOGY

ICES CM 2014/SSGESST:06

REF. SCICOM, WGFAST, & ACOM

First Interim Report of the Working Group on Target Classification (WGTC)

3–4 May 2014

New Bedford, USA

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2014. First Interim Report of the Working Group on Target Classification (WGTC), 3-4 May 2014, New Bedford, USA. ICES CM 2014/SSGESST:06. 15 pp.

Contents

Executive summary **1**

1 Administrative details **2**

2 Terms of Reference a) – z) **3**

3 Summary of Work plan **4**

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

5 Progress report on ToRs and workplan **4**

6 Revisions to the work plan and justification **4**

7 Next meetings (Interim reports only) **4**

Annex 1a: List of participants to New Bedford meeting **5**

Annex 1b: List of WG participants not participating in New Bedford **7**

Annex 2: Recommendations **7**

Annex 3: Chapters and authors to proposed CRR **8**

Executive summary

The Working Group on Target Classification, chaired by Rolf J. Korneliussen, met for the first time 3–4 May 2014 in New Bedford, USA, with the mandate to prepare a Co-operative Research Report (CRR). Twenty-eight experts had volunteered to contribute to the work, and 16 of those met in New Bedford. The written preparation prior to the meeting was kept to a minimum to assure that the participants started as close as possible on the same level. There were nine presentations on target classification on the meeting.

The proposed Cooperative Research Report (CRR) will avoid content of previous CRRs, e.g. Report on Echo Trace Classification (CRR 238), and Acoustic Seabed Classification of Marine Physical, and Biological Landscapes (CRR 286). The meaning of the term "Target classification" was discussed, and it was decided that it is to be regarded as essentially "species identification". This proposed CRR is suggested to contain broad advices of needs to classify targets as well as examples, but is not suggested to be a strict recipe of how to classify targets.

The structure, i.e. the chapters of the proposed CRR was discussed and decided. Contributors to each chapter were allocated.

1 Administrative details

Working Group name

Working Group on Target Classification (WGTC)

Year of Appointment

2014

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

Chair(s)

Rolf J Korneliussen, Norway

Meeting venue

New Bedford, United States of America

Meeting dates

3–4 May 2014

2 Terms of Reference a) – z)

ToR	Description	Background	Science Plan topics addressed	Dur.	Expected Deliverables
a	Review, summarize and report on the literature regarding (1). Acoustic systems currently used in fisheries research and surveys, (2) theoretical principles of target classification and (3) methods currently being practiced;	The ICES reference for acoustic target classification needs to be useful to practitioners of fisheries acoustics and ecosystem surveys that produce data for stock management. The first step in this process is to review, summarize and report on the literature regarding the methods that are currently used in fisheries research and surveys. The theoretical principles for target classification must be summarized, and the methods currently being practiced must be evaluated		2 year	Review document presented to WGFAST in 2015
b	Develop recommendations protocols for methods to be used for target classification during ecosystem surveys including (1) commonly used acoustic systems used in fisheries research and surveys (2) principles of classification, general and specific to these selected systems (3) standard protocols for classifying multifrequency data	There is a need for recommendations to the ICES community for methods to be used for acoustic target classification. These methods cover commonly used acoustic systems used in fisheries research and ecosystem surveys, and must be generic enough for application in systems not specifically considered. The methods must be practical and based on solid theoretical principles.		Year 3	Recommendations document presented to WGFAST in 2016
c	Based on ToR a) and b) a CRR proposal should be developed for SCICOM consideration.	There is a recognized need to comprehensively document the current theory and recommended practice of acoustic target classification for use in Fisheries Science and ecosystem surveys, and publish them in an easily accessible report.		Year 3	CRR proposal submitted for consideration by SCICOM in Septebmer 2016

3 Summary of Work plan

Year 1(2014 – 2015)	Initiate the work
Year 2(2015 – 2016)	Finalize the review (ToR a)
Year 3 (2016 – 2017)	Finalize recommendations and prepare a CRR proposal (ToRs b and c)

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

- Structure of final report decided
- Authors to chapters and subchapters of proposed CRR decided

5 Progress report on ToRs and workplan

- Progress by ToR: initial year
- Changes/ Edits/ Additions to ToR: no changes
- Cooperation with other WG: WGFAST
- Cooperation with Advisory structures: none
- Science Highlights: none

6 Revisions to the work plan and justification

No revisions – using original work plan.

7 Next meetings (Interim reports only)

Nantes, France, 29–30 May 2015 (approx.)

Vigo, Spain, May 2016 (approx.)

Annex 1a: List of participants to New Bedford meeting

Name	Address	Phone/Fax	E-mail
Rolf J Korneliussen **Chair**	Institite of Marine Research, PO Box 1870 Nordnes, 5817 Bergen, Norway	+47 488 97 388 / +47 55 23 85 31	rolf.korneliussen@imr.no
Alex De Robertis	Alaska Fisheries Science Center 7600 Sand Point Way, NE, mail stop Fy/AKC1 Seattle, WA 98115 USA	FAX 206 526-6723	Alex.DeRobertis@noaa.gov
Ian McQuinn	850, route de la Mer Mont-Joli, Québec Canada, G5H 3Z4	+1 (418)775-0627 +1 (418)775-0740	Ian.McQuinn@dfo-mpo.gc.ca
Anne Lebourges-Dhaussy	IRD, UMR LEMAR IRD Bretagne, ZI de la Pointe du Diable, BP70 29280 Plouzané, France	+33 2 98 22 45 05	anne.lebourges.dhaussy@ird.fr
J. Michael Jech	NEFSC 166 Water St Woods Hole, MA 02543 USA	508-495-2353 / 508-495-2115	michael.jech@noaa.gov
Gareth Lawson	Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA	+1 508 289 3713 /+1 508-457-2134	glawson@whoi.edu
John Horne	University of Washington PO Box 355020 Seattle, Washington 98195-5020 USA		jhorne@uw.edu
Dezhang Chu	NOAA/NMFS/NWFSC/FRAM 2725 Montlake Blvd. E. Seattle, WA 98112 USA	206-861-7602206-861-7602 / 206-860-6792	dezhang.chu@noaa.gov
Sascha Fässler	Wageningen IMARES PO Box 68 1970 AB IJmuiden Netherlands		sascha.fassler@wur.nl
Rudy Kloser	CSIRO, Hobart, Tasmania, Australia	+61 3 6232 5389	Rudy.Kloser@csiro.au

Charles H Thompson	Southeast Fosheries Science Center, Mississippi Laboratories Rm2010, 1021 Balch Blvd, Stennis Space Center, MS 39529 USA	+1 228 688 2097	Charles.h.thompson@noaa.gov
Federico Iriarte	Fishing Harbour, Tema CE 11254, Tema, Ghana	+233 544 316 472 / +233 303 206 218	Federico.Iriarte@mwbrands.com Faya2005s@yahoo.com
Mathias Scaber	Thünen-Institute of Sea Fisheries Palmaille 9, 22767 Hamburg Germany	+49 (0)40 38905 173 / +49 (0)40 38905 264	matthias.schaber@ti.bund.de
Sven Gastauer	Sven Gastauer Wageningen UR Centre for Marine Policy PO Box 1528 8901 BV Leeuwarden Netherlands		Sven.gastauer@postgrad.curtin.edu.au
Briony Hutton	GPO Box 1387, Hobart, Tasmania, Australia, 7001	+61 3 6231 5588 /+61 3 62341822	briony.hutton@echoview.com
Reka Domokos	Ecosystems and Oceanography Division, Pacific Islands Fisheries Science Center, National Marine Fisheries Service, NOAA, 2570 Dole Street Honolulu HI 96822-2396 USA	8089835368	reka.domokos@noaa.gov

Annex 1b: List of WG participants not participating in New Bedford

Name	Address	Phone/Fax	E-mail
Mathieu Doray	Ifremer, France		Mathieu.Doray@ifremer.fr
Pierre Petigas	Ifremer, France		Pierre.Petitgas@ifremer.fr
Laurent Berger	Ifremer IMN/NSE/AS BP 70 29280 Plouzane France	+33 (0) 2 98 22 47 00 / +33 (0) 2 98 22 44 52	laurent.berger@ifremer.fr
Sophie Fielding	BAS, UK		sof@bas.ac.uk
Chris Wilson	NOAA/AFSC, USA		chris.wilson@noaa.gov
David Demer	NOAA/SWFSC, USA		david.demer@noaa.gov
Marian Peña Saenz	IEO, Sain		marian.pena@ba.ieo.es
Sergej Goncharev	VNIRO, Russia		sgonch@vniro.ru
Svetlana Kasatkina	ATLANTNIRO, Russia		ks@atlant.baltnet.ru
Stephane Gauthier	Institute of Ocean Sciences, 9860 West Saanich Road, PO Box 6000, Sidney, British Columbia, Canada V8L 4B2	1-250-363-6587 / 1-250-363-6690	Stephane.Gauthier@dfo-mpo.gc.ca

Annex 2: Recommendations

ICES Working Group on Target Classification did not reach any recommendations within the 2014 meeting.

Annex 3: Chapters and authors to proposed CRR

Contents **1**

1 Forward **1**

2 Executive overview **1**

2.1 Why do we need classification?

3 Terminology **1**

4 Introduction **1**

4.1 What is a target (in our context)? 1

4.2 What should this report not contain (and why) 1

4.3 What is target classification – levels of target classification 1

5 General limitations in acoustic target classification technology **1**

5.1 Issues related to instrumentation 1

5.2 Issues related to validation 1

5.3 Issues related to organisms 1

6 Steps of target classification **1**

6.1 Type of data: acoustical 1

6.2 Data aquisition – how to collect and what to collect 1

6.3 Preprocessing 1

7 Target classification – analysis approaches **1**

7.1 Empirical approach 1

7.1.1 Subjective 1

7.1.2 Objective 1

7.1 Model-based approach 1

7.2.1 Theoretical basis for classification 1

7.1.2 Types of models 1

7.2.3 Model input parameters 1

8 Classifiers used **1**

8.1 Typical classifiers used 1

8.2 Classifiers that have been used previously 1

9 Methods of verifications (example based) **1**

10 Anticipating future directions **1**

11 Acknowledgements **1**

12 References **1**

13 Appendices **1**

Forward

Rolf J Korneliussen

Acoustic data are currently being collected from a variety of acoustic systems in many countries to address a range of ecosystem monitoring and stock management objectives. There is no ICES CRR covering this topic, but there are two CRR for related topics: CRR 238 (2000), Editor: Dave Reid, Report on Echo Trace Classification; and CRR 287 (2007), Editor John Anderson on Acoustic seabed classification of marine physical and biological landscapes. Note that the CRR-238 focused mostly on single-frequency and school-based methods, and that at the time work on multifrequency and wideband methods (while covered in that CRR) was more in development but now is much more mature.

There is also a comprehensive report from an EU financed project: Fernandes, P.G., Korneliussen, R.J., Lebourges-Dhaussy, A., Masse, J., Iglesias, M., Diner, N., Ona, E., *et al.,* 2006. The SIMFAMI project: species identification methods from acoustic multifrequency information. While much of the theoretical principles of those reports are still relevant, target classification is a fast moving field. The methods need to be expanded to include currently used technologies (e.g. multibeam and broadbandwidth systems). There exists an urgent need to evaluate recent work and to develop recommendations for protocols appropriate to target classification used in fisheries research and ecosystem surveys. This need has been identified by a number of ICES Member Countries and observer countries and has been conveyed to WGFAST and SCICOM.

2 Executive overview

Rolf J. Korneliussen, John Horne, (+all)

- Define target audience (whom is this report written for?) – a guidance work flow
- Simple use: chapters …… (Include examples, figures)
- Common users: chapters … (Include examples, figures)

  Advanced use: chapters … (Include examples, figures) the names, symbols, and units of physical quantities must be precisely defined to assure effective scientific communication. The following terminology, based mostly on MacLennan

2.1 Why do we need classification? (Necessary component of analysing echograms)

- Accurate, efficient and objective data interpretation
- Consistent and reproducible results
- Uncertainty quantification
- To better assess and understand the various components of an ecosystem
- To produce more objective data for stock management (See ToR)...

3 Terminology (Refer MacLennan *et al.* + SGCal_CRR)

J. Michael Jech, Rolf J Korneliussen, Dezhang Chu, Charles H. Thompson, David Demer

The names, symbols, and units of physical quantities must be precisely defined to assure effective scientific communication. The following terminology, based partly on Demer *et al.* (2014XXX – SGCal_CRR) which is mostly based on MacLennan *et al.* (2002) is used consistently throughout this Cooperative Research Report and can be adopted for more general use in the field of Fisheries Acoustics.

Symbols uniquely represent a term. All symbols for variables are italicised. Any symbol for a variable (x) which is not logarithmically transformed is lower-case. Any symbol for a variable with units of decibels ($X(\mathrm{dB}) = 10Log(x/x_{ref})$), relative to a reference value (xref), is capitalized.

Term	Symbol	Unit	Description
Depth	d	m	The vertical distance below the sea surface.
Frequency	f	kHz	Number of complete cycles of a periodic wave per unit time.
Acoustic wavelength	λ	m	Distance spanned by one cycle of a periodic pressure wave.
Pulse duration	τ	s	The duration of a sound pulse.
Range	r	m	Distance between objects, e.g. the transducer and the target.
Acoustic power	pa	W	Acoustic energy per unit time.
Absorption coefficient	αa	dB m^{-1}	A metric of the reduction in ia with r resulting from the conversion of pa to heat.

Term	Symbol	Unit	Description
Sampled volume	V	m^3	The volume contributing to a received signal.
Volume backscattering coefficient	sv	m^{-1}	The backscattering cross section per unit of water volume.
Volume backscattering strength	Sv	dB re 1 m^{-1}	Ratio of sv and the area of a sphere with radius r0, in decibels.
Area backscattering coefficient	sa	m^2 m^{-2}	The integral of sv over a range of depths.
Nautical-area scattering coefficient	sA	nautical $mile^{-2}$ m^2	sa multiplied by $4\pi 18522$.

4 Introduction

Rolf J Korneliussen, Dezhang Chu, (+all); John Horne, Alex De Robertis, Ian McQuinn, Réka Domokos, Mathieu Doray

4.1 What is a target (in our context)

- Single organism and aggregations of organisms. For the purpose of this report biological targets are desired.
- Physical, e.g. bubble plumes, turbulence, suspended materials. For this report, these are unwanted targets.

4.2 What this report should not contain (and why)

- Bottom classification (since there is a CRR report on that)
- Echo-trace classification based on morphology of single-frequency echosounder data (since there is a CRR report on that)
- Target classification of non-acoustic data

4.3 What is target classification – levels of target classification (John Horne, Alex De Robertis, Ian McQuinn, Réka Domokos, Rolf J. Korneliussen)

- Level 1: "Discrimination". Distinguish wanted or unwanted targets, i.e. very simple "categorization".
- Level 2: "Categorization". Assign common acoustic characteristics to coarse categories.
- Level 3: "Identification". Interpretation of the categories generated in previous levels. Assign to narrow biological groups.

5 General limitations in acoustic target classification technology

Rolf J. Korneliussen, Sasha Fässler, Sven Gastauer, Alex De Robertis, Dezhang Chu, Sasha Fässler, Réka Domokos, Marian Peña Saenz, Laurent Berger, Mathieu Doray, (Stephane Gauthier)

5.1 Issues related to instrumentation (Rolf J Korneliussen, Sasha Fässler, Sven Gastauer, Marian Peña Saenz, and Laurent Berger)

- Noise limits over multiple frequencies. Maximum range limitation, i.e. S/N ratio after the data are cleaned.
- Frequency selection: is the appropriate frequency-band for classification of a specific target available? ("Right tool for the job")
- Volume sampling and spatial overlap.
- Selectivity of targets: small target bias with range.

5.2 Issues related to validation (Alex De Robertis write one paragraph)

- Ground-truthing (physical sampling and related issues that may affect and bias interpretation of results).biological targets are the desired.

5.3 `Issues related to organisms (Dezhang Chu, Réka Domokos)

- Limited knowledge of scattering properties of organisms
- Changes in organisms scattering characteristics over time and space
- Mixed species assemblages
- Stochastic scattering properties

6 Steps prior to target classification

Rolf J. Korneliussen, Laurent Berger, Sasha Fässler, Briony Hutton, Stephane Gauthier

6.1 Type of data: acoustical (...)

- Multifrequency
- Broadband: continuous band (define what is wideband)
- Wideband: multifrequency or broadband

6.2 Data acquisition (Rolf J Korneliussen, +??)

- How to collect and what to collect

6.3 Preprocessing (Ian McQuinn, Rolf J. Korneliussen, Briony Hutton)

- data improvement, data cleaning, quality control, Sv & TS threshold, deciding what is "noise" (i.e. zooplankton are noise in the context of swimbladder-bearing fish), what is unwanted signal, what is wanted signal.

7. Target classification – analysis approaches

Rolf J. Korneliussen, Rudy Kloser, Stephane Gautier, Laurent Berger, Mathieu Doray

7.1 Empirical approach (i.e. based on data; Rolf J. Korneliussen, Rudy Kloser, Stephane Gautier, Marian Peña Saenz, Laurent Berger, Mathieu Doray)

7.1.1 Subjective

- analyst scrutiny

7.1.2 Objective (Rolf Korneliussen, Rudy Kloser, Stephane Gauthier, Laurent Berger (?), Mathieu Doray)

- Relative frequency response (including resonance peaks; *Rolf Korneliussen*)
- Threshold target strength (*Rudy Kloser, Stephane Gauthier*)
- Echo-envelope characteristics (i.e. echo measures; NB! depends on physical instrument properties such as beam width and frequency bandwidth; c.f. George Rose, Salabrin, - Single frequency; *Laurent Berger (?), Mathieu Doray)*
- Image analysis based on aggregation characteristics: shape, rates-of-change: (temporally-, spatially-, or amplitude indexed pixels). **PS! Do not include if this is in CRR EchoTrace report.**

7.2 Model-based approach (Dezhang Chu, Gareth Lawson, Anne Lebourges-Dhaussy, John Horne, J Michael Jech, Sophie Fielding, Marian Peña Saenz)

7.2.1 Theoretical basis for classification

- Expands ranges beyond possible measurements
- Aids in verification and interpretation of empirical data
- Simulations (controlling for sets of variables that may affect results).

7.2.2 Types of models

- Analytical (closed form, e.g. DWBA solution for ellipsoid)vs. numerical (e.g. finite element model)
- Exact (sphere, infinite cylinder, infinite plane)vs. Approximate "everything else")

7.2.3 Model input parameters

- Material properties (sound speed, density)
- Environmental properties (sound speed and absorption)
- Target shape (morphology)
- Target anatomy
- Orientation

8 Classifiers used

Rolf J. Korneliussen, Rudy J. Kloser, Dezhang Chu, Pierre Petitgas, John Horne, Mathieu Doray

8.1 Typical classifiers used (Ian McQuinn, Rolf J. Korneliussen, Rudy J. Kloser, Dezhang Chu, Pierre Petitgas, John Horne, and Mathieu Doray)

- Thresholding (e.g. TS, frequency response, multifrequency thresholding……)
- Inversion (e.g. SVD)
- Gaussian mixture models (supervised, unsupervised, semi-supervised)
- Discriminant function analysis (used currently)

8.2 Classifiers that have been used previously (John Horne writes one or two paragraphs)

Reference to literature links only and also listing cautions!!!!!)

- Discriminant function analysis (not used anymore)
- Ordination (factor analysis, PCA)
- Regression tree/forest (Ex. Paul Fernandes)
- Neural network (CRR EchoTrace ?)

9 Methods of verification (example based)

Matthias Scaber, Stephane Gauthier, Réka Domokos, Sophie Fielding

- Biological sampling (nets and trawls, multi-opening systems, other forms of capture)
- Optical methods (video, still-photos, optical devices for zooplankton and small particles such as LOPC/UVP/OPC/ZOOVIS/VPR, divers)

10 Anticipating future directions

Rolf J. Korneliussen, Rudy J. Kloser, Marian Peña Saenz, (+all)

(Kept simple):

- 3D data - e.g. ME70 or similar (Marian Peña Saenz)
- 4D data - e.g. MS70 or similar, DIDSON?, CodaOctopus Echoscope?, Imagenics, WASP

11 Acknowledgements

...

12 References

Black font indicates peer-reviewed primary literature. Grey font indicates secondary literature (e.g. reports, conference proceedings).

ACOUSTIC SYMBOLS / GENERAL ACOUSTICS:

D. N. MacLennan, P. G. Fernandes, and J. Dalen, "A consistent approach to definitions and symbols in fisheries acoustics", ICES Journal of Marine Science 59, 365-369 (2002).

P. Lunde, A. O. Pedersen, R. J. Korneliussen, F. E. Tichy, and H. Nes, "Power-budget and echo-integrator equations for fish abundance estimation", Fisken og Havet no. 10/2013, Institute of Marine Research, Bergen, Norway, 39 p.

D. N. MacLennan, "Acoustical measurements of fish abundance", J. Acoust. Soc. Am. 87(1), 1-15 (1990).

NOISE REMOVAL / NOISE REDUCTION:

Korneliussen, R. J. 2000. Measurement and removal of echo integration noise. ICES Journal of Marine Science, 57: 1204–1217.

Ona, E., and Traynor, J. 1990. Hull mounted, protruding transducer for improving echo integration in bad weather. ICES Document CM 1990/B: 31.

DATA COLLECTION:

Korneliussen, R. J., Diner, N., Ona, E., Berger, L., and Fernandes, P. 2008. Proposals for the collection of acoustic multifrequency acoustic data. ICES Journal of Marine Science, 65: 982–994.

Pedersen, A. 2006. Effects of nonlinear sound propagation in fisheries research. PhD thesis, University of Bergen. 308 pp.

F. E. Tichy, H. Solli and H. Klaveness, "Nonlinear effects in a 200-kHz sound beam and consequences for target strength measurement", ICES Journal of Marine Science 60, 571-574 (2003).

SPECIES IDENTIFICATION:

R. J. Korneliussen, "Analysis and presentation of multifrequency echograms", Dr Scient. thesis, University of Bergen, Department of Physics, Bergen, Norway (2002), 182 p.

Fernandes, P. G., Korneliussen, R. J., Lebourges-Dhaussy, A., Masse, J., Iglesias, M., Diner, N., Ona, E., *et al.* 2006. The SIMFAMI project: species identification methods from acoustic multifrequency information. Final Report to the EC Number Q5RS-2001-02054 (Report accessible from any of the authors).

13 Appendices

Gareth Lawson, Alex De Robertis, Briony Hutton, Rolf J. Korneliussen, Federico Iriarte, Briony Hutton, Sophie Fielding

Appendix 1: Case study / examples (Gareth Lawson)

Appendix 1: Case study / examples (Alex De Robertis)

Appendix 1: Case study / examples (Briony Hutton)

Appendix 1: Case study / examples (Rolf J. Korneliussen)

Appendix 1: Case study / examples (Federico Iriarte)

Appendix 1: Case study / examples (Sophie Fielding)