Final report of the MESOBROAD Project.

Project: "Application of the broadband echosounder to the study of micronecton and macrozooplankton" (MESOBROAD)

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Introduction

The MESOBROAD project extended a previous connecting network between the IEO in Spain and the IMR in Norway that dated back to the PELASSES project in the early 2000s and has since then continued through the WGFAST and WGTC meetings among other. This connection was widened with MESOBROAD project by including the collaboration of Per Lunde from Bergen University that has worked in the past with Rolf Korneliussen (Korneliussen and Lunde, 2016). Lunde's more theoretical background and experience on acoustics provides the theoretical basis for improved understanding of conventional methods and instruments used today.

The final goal of the project was the study of mesopelagic species with the broadband echosounder EK80, mainly gas bearing myctophids and bristlemouths, and macroplancton fluid like species such as krill, medusae or pteropods. In order to apply this new technology to the study of these deep-habitats, several objectives needed to be done first:

- Calibration of the EK80 at 2 ms pulse length. One of the advantages of the broadband technology is the independency of pulse length and vertical resolution of the echogram. The pulse length can be increased in order to see deeper waters without compromising the minimum cell that can be studied.
- Analysis of the signal-to-noise ratio (SNR) of broadband at different thresholds. One of the shortcomings of hull-mounted echousounders is the limited depth that can be studied due to signal attenuation caused by absorption and beam spreading. Although theory suggested that the SNR should be better for broadband (EK80) than narrowband (EK60) the possibility of vessel noises not seen until now with EK60 showing at different frequencies and spreading along the spectrum was expected.
- Comparison of biomass and abundance estimations from both systems. Again, theory says that both systems should give similar values but small deviations in the processing of broadband data can sum up or multiply ending up in substantial differences.
- Search of resonant spectrums due to bristlemouths at 38 kHz at the Deep Scattering Layer. Analysis of the original continuous spectrum as well as of the split spectrum converting broadband signatures into EK60-like frequency responses.

Data sampling

An agreement was established with Lars Andersen from SIMRAD (Norway) to employ the new EK80 system during a Spanish survey to start working with this technology. A first attempt of data recording was carried out in April 2015. MAFIA survey was scheduled for this month on board RV Hespérides, from Brazil to the Canary Islands in Spain. Some unexpected issues with Brazilian customs prevented this recording. A second and successful attempt took place in July 2015, during the SCAPA survey on board RV Ramón Margalef. EK80 data was recorded near Gijón city from the 11th to the 27th of July 2015. Installation and calibration tests were carried out previously. The use of a multiplexer based on designs facilitated by IMR allowed to record alternatively EK60 and EK80, one ping for each.

Analysis of the signal-to-noise ratio (SNR) of broadband data at different thresholds was carried out. One of the shortcomings of hull-mounted echosounders is the limited depth that can be studied due to signal attenuation caused by absorption and beam spreading. Although theory suggests that the SNR should be better for broadband (EK80) than narrowband (Ek60) the possibility of vessel noises not seen until now with EK60 showing at different frequencies and spreading along the spectrum was expected. This was indeed the main problem encountered during broadband installation. A thorough analysis of the electrical devices surrounding the broadband system was carried out, removing the main noise peaks visible at the spectrum. The comparison of both systems showed little improvement in the maximum depth reached before the noise started surmounting the signal level and showed the characteristic noise stripes. This could be due to remaining electrical noises spreading among the broadband spectrum, as well as to decimation or higher white noise levels in broadband data.

The main mesopelagic species in the area are myctophids, bristlemouths and krill, with the first two being the stronger scatterers due to the swimbladder. The best way to identify swimbladdered fish is by employing frequency bands that include the resonant frequency at the habitat depth. The corresponding resonant frequencies are ~18 kHz for myctophids and ~38 kHz for bristlemouths. However, the available acoustic transducers at those frequencies were not considered suitable for broadband in principle. Nevertheless, several acousticians have studied the possibility of using those transducers with a broadband system. We focused mostly our efforts to the 38 kHz transducer, due to the rule of thumb generally considering the possibility of broadband as 10% of the frequency (i.e. a 4 kHz band is expected for a 38 kHz). This frequency was correctly calibrated and employed later on. The remaining calibrating time was employed trying to calibrate the 18 kHz transducer, but the results were quite dissimilar to the theoretical models. Later talks with North American colleagues have revealed that 18 kHz can indeed be used for broadband studies, showing expected resonances, but it is very much dependent on particularities of the transducers. We expect to be able to conduct further calibration trials with 18 kHz although SIMRAD is developing new transducers with alternative designs, more suitable for broadband applications.

Converting EK80 broadband data into EK-like split data

Broadband data imply a huge increment in the data storage (about five times more than EK60) and the need for computer performance. This could limit the use of broadband in the future. One possible shortcut is to convert broadband data into EK60-like data, extracting a number of discrete frequencies as the result of averaging the values from sub-bands of the total spectrum. In order to do that, the minimum band required needed to be studied. General knowledge indicated that a minimum of 4 -5 kHz of band was needed, but has never been properly analysed. This can be critical for lower frequencies, were the total band available is narrower, reducing the number of possible discrete frequencies. How the broadband signal was created can also reduce the band available. While short ramping increments the intensity of the signal progressively with time giving a square envelope of short stable area, fast ramping employs a very short delay to reach the maximum power (see figure 1). This means that the lateral extremes in short ramping present a lower signal-to-noise ratio that in some cases may be insufficient for acoustic studies of weak scatterers such as krill. Slow and fast ramping have different benefits that will not be analyzed in this report. Our data was recorded with slow ramping for the 38 kHz frequency band and with fast ramping for the 120 kHz spectrum. Several overlapping and not overlapping sub-bands of different width were tested for both frequencies, adding some lateral cuts for the slow ramping with 38 kHz (see Table 1 for the final bands applied).

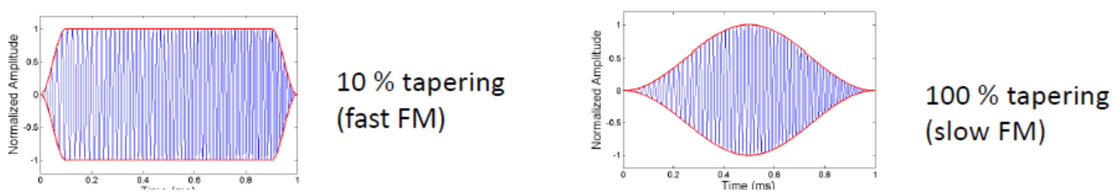


Figure 1: differences in broadband signal creation with slow and fast ramping (tapering). Fast ramping reaches quickly the maximum power while slow ramping takes longer to reach the maximum.

EK60	18	38	70	120	200	333			
EK80 band	36-39	37-40	36-40	95-108	108-121	121-134	134-147	147-160	95-120
Middle frequency	38	37	38	101	114	127	140	153	127

Table 1: Final splitting bandwidths employed to convert EK80 broadband data into EK60-like split data and EK60 frequencies available on board RVMargalef.

EK80 and EK60 comparison

After the stage done at IMR in Bergen, Norway for two months in 2015, collaboration with Rolf Korneliussen and Gavin Macaulay continued by email. The first combined works have focused on the comparison between EK60 and EK80 data, as it is of most interest for the acoustic community that, although is very keen on incorporating EK80 and its added functionality, is concerned with the stability of the results, particularly for temporal series of stock assessment.

Different comparison approaches were followed: while Marián Peña focused on the comparison between EK60 data and multi-frequency data extracted from broadband data (Peña et al, 2016), Gavin Macaulay compared CW and FM data, both from broadband. Marian's results showed similar results for EK60 and EK80 data at 38 kHz, but some differences at 120 kHz, with EK80 data showing a smoothed version of EK60 data, with much less variability and minimum Sv values much elevated than EK60 data (see Figures 2 to 4). A first explanation considered is that the post-processing applied to broadband was averaging the results. Why this was affecting much more to the 120 kHz frequency band was still unknown. Further analysis of the band splitting procedures was needed. However, no difference was found between EK80 data at 120 kHz using the whole available band and only the center 13 kHz band (see Figure 5).

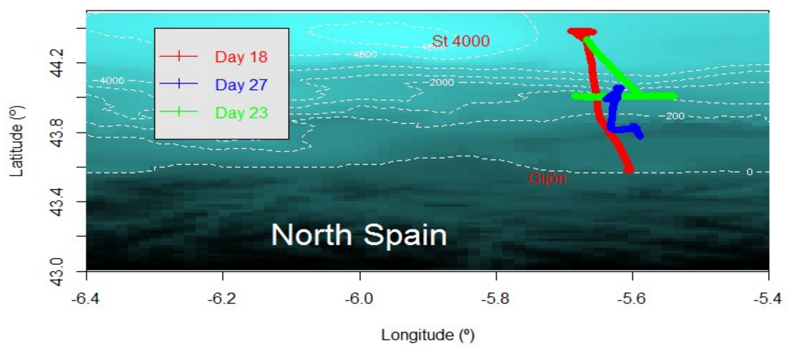
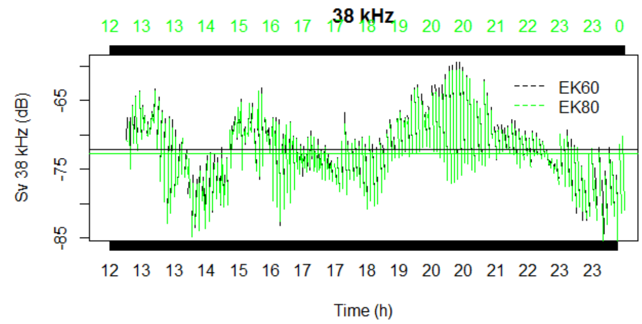


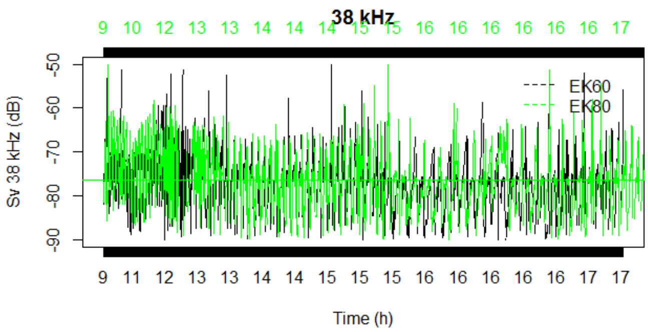
Figure 2: Location of the three-day data chosen to compare EK60 and EK80 data.



a) 100 m

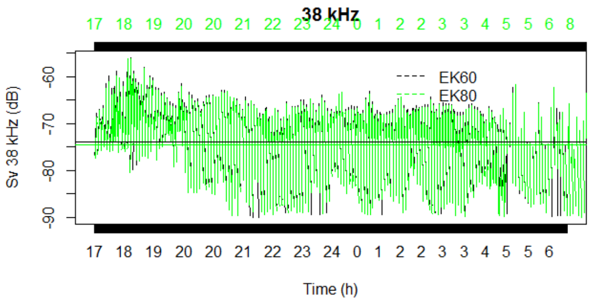
38 kHz	Min.	Mean	Max.
EK60	-84.38	-72.19	-59.40
EK80	-89.22	-72.69	-60.42

a) 100 m depth



b) Varying depth up to 2000

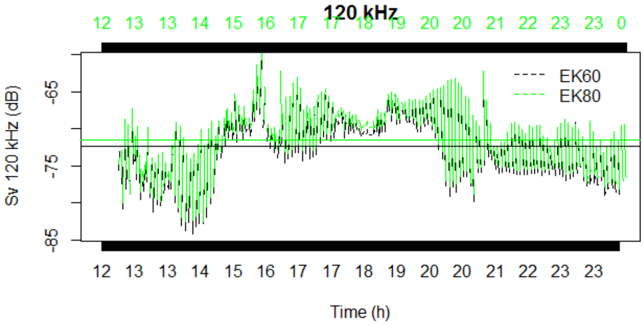
38 kHz	Min.	Mean	Max.
EK60	-89.99	-76.49	-50.07
EK80	-89.92	-76.42	-50.09



c) 200 m

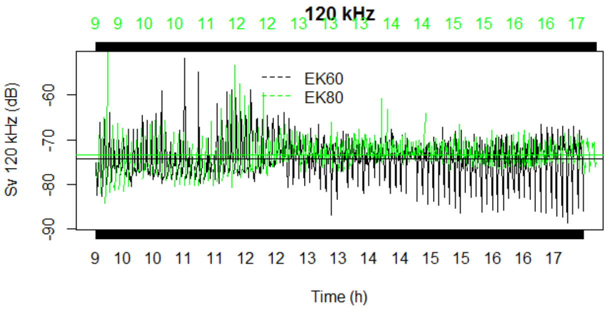
38 kHz	Min.	Mean	Max.
EK60	-89.98	-74.02	-56.01
EK80	-89.95	-74.49	-53.21

Figure 3: Comparison between EK60 (black) and split EK80 data (green) at 38 kHz and main statistics. Three different datasets with different bathymetry (and thus different ambient noise characteristics) were compared. No big differences were encountered for the 38 kHz echograms.



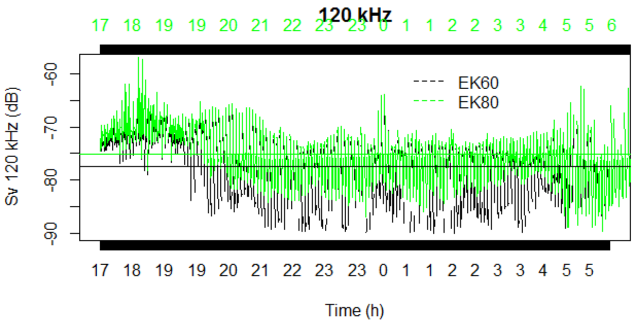
a) 100 m

120 kHz	Min.	Mean	Max.
EK60	-84.13	-72.36	-60.70
EK80	-82.51	-71.48	-59.61



b) Varying depth up to 2000

120 kHz	Min.	Mean	Max.
EK60	-88.66	-74.37	-51.71
EK80	-84.22	-73.31	-50.06



c) 200 m

120 kHz	Min.	Mean	Max.
EK60	-89.96	-77.35	-57.69
EK80	-89.54	-75.17	-56.97

Figure 4: Comparison between EK60 (black) and split EK80 data (green) at 120 kHz and main statistics. Three different datasets with different bathymetry (and thus different ambient noise characteristics) were compared. This frequency showed similar mean values for broadband and narrowband, but clear differences appeared at the minimum and maximum values, as seen at the figures.

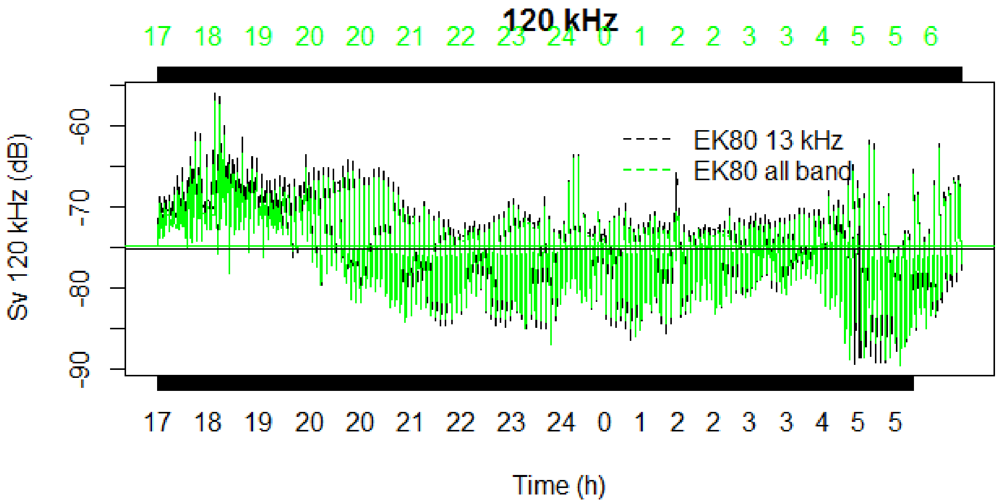


Figure 5: Comparison between split EK80 data at 120 kHz using the whole available band (95-160 kHz) and only the center 13 kHz band (121-134 kHz). One of the works carried out was the study of the minimum band needed around a particular frequency to get an accurate average of the broadband signal in that band. Using a 13 kHz band around 120 kHz gave very similar values to using the whole available band.

Further tests were carried out with the 200 kHz band by Rolf Korneliussen and presented at the ICES training course that took place in Bergen in December 2016 (see Figure 6) .

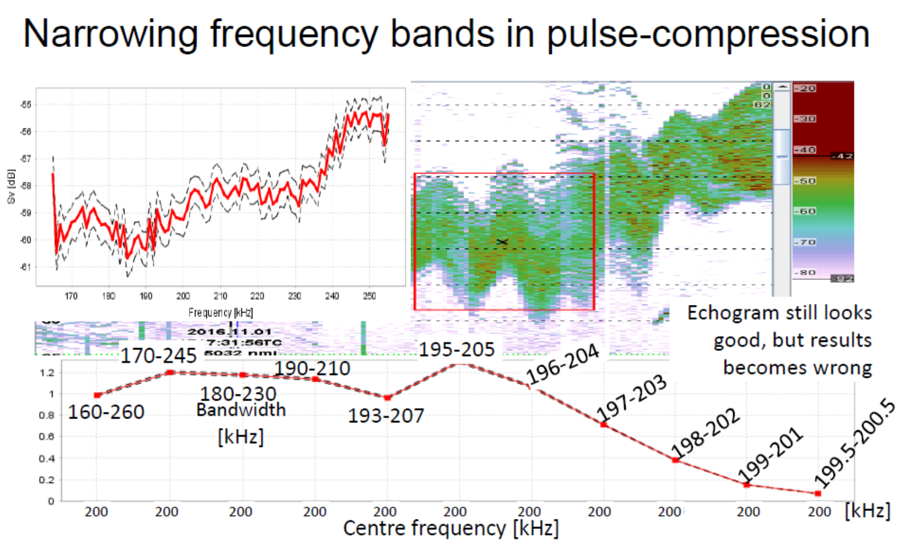


Figure 6: difference in NASC values resulted on the use of different sub-bands to split 200 kHz broadband data into EK60-like data. Similar results are found when employing bands from 160-260 kHz to 195-205 kHz, but the NASC values decreased slowly after the bands were narrower than 10 kHz. It is suspected that the sampling frequency could be a cause of the reduced values for the reduced bandwidth.

Dissemination

Two presentations were made on the annual acoustic ICES Working Group on Fisheries and Acoustic Science and Technology (WGFAST) in Vigo (19-22 April 2016): Marián Peña presented her comparisons between EK60 data and multi-frequency data extracted from broadband data (Peña et al, 2016), and Gavin Macaulay presented alternative comparison between CW and FM data, both from broadband (Macaulay, 2016). Further results are expected to be presented in 2017 at the WGFAST that will take place in New Zealand.

Marian Peña was asked to participate as convener in the discussion forum that took place within the WGFAST 2016, where also members of the industry presented their updates (see annex I for agenda and report).

To further disseminate the project, a website was published within the Balearic centre of IEO web here, and news was published with information on the WGFAST participation and presentations, linking the project website and the ICES science fund web.

Marián Peña attended the advanced acoustic course focused on EK80 data processing that took place in Bergen (Norway) in December 2016, carried out on board the RV Sars, with Norwegian and north-American experts as teachers. Rolf Korneliussen was one of the teachers.

Future work

The big size of EK80 data files and the still in development state of commercial software imply a long time to process and analyze these data. However, steady progress is being made, and a great feedback from the attendees at the WGFAST proves the relevance of these pioneer works.

At least a common publication with the mentioned collaborators is expected, focused on the comparisons between EK60 and EK80 data. Other works will involve the development of masks to identify mesopelagic species from broadband data, and the study of these species behaviour .

A new survey focused on the use of broadband devices for the study of scattering layers in the Bay of Biscay onboard R/V Thalassa is taking place from 27/05 (Brest) to 02/06/2017 (Brest). It is a French-organised survey but several European colleagues have been invited to favour a workshop-like meeting in the field. Marian Peña will attend this survey.

Conclusion

The main objective of the MESOBROAD project was to accomplish the preliminary studies necessary to apply broadband technology to the study of mesopelagic species, particularly swimbladdered fishes that present a characteristic resonance. This objective was achieved by establishing the basis of equipment installation and calibration on board RV Margalef, analyzing the improvements in terms of SNR with broadband, testing the minimum subbands necessary to convert broadband data to discrete frequencies equivalent to EK60 data and comparing EK60 and EK80 data. Some early work on fish resonance location was also implemented but this needs further work.

References

Lunde, P.; Korneliussen, R.J. Power-Budget Equations and Calibration Factors for Fish Abundance Estimation Using Scientific Echo Sounder and Sonar Systems. J. Mar. Sci. Eng. 2016, 4, 43.

Gavin Macaulay. Comparing echo integration results from the Simrad EK60 and EK80. WGFAST 2016, Vigo

Marián Peña, Rolf Korneliussen, Gavin Macaulay. Preliminary results on the comparison between EK60 and EK80 data (after splitting). MESOBROAD project. WGFAST 2016, Vigo

ANNEX I: Wideband Forum agenda and report

Wideband Forum 2016 ICES WGFAST, Vigo, Spain
1600-1700, Tuesday, 19 April 2016
Conveners: Mike Jech, Marian Peña, Ben Scoulding

Purpose: Continue discussion of wideband acoustic technology and receive updates on technologies, workshops, and on-going developments.

Background: An open forum on the topic of wideband acoustics was convened immediately following the close of the SOMEAcoustics symposium on Thursday 28 May. The conveners were Gareth Lawson, Andone Lavery, Tom Weber, and Mike Jech. With over 100 participants, the discussion was broad-ranging and productive. Recommendations and suggestions from that discussion are used as a starting point for this forum, followed by an open discussion on any wideband topic of interest.

Discussion Topics:

- ***Update on EK80 hardware and software*:** *(Lars Andersen, Simrad)*
  - Version updates.
  - New transducer designs (e.g., 18 and 38 kHz)
  - Use of FM at 18 and 38 kHz with respect to "fatal overload" messages.
  - Calibration procedures.
  - Frequency-dependent gains.
- ***Update on EK80 manual*:** Broadband acoustics, and the EK80 in particular, requires some kind of manual. Arguably, best would be for it to be a peer-reviewed publication. Perhaps it could have some kind of working DOI that would allow appendices to be added as methods/approaches evolve. The ICES Survey Protocols (SISP) series offers this possibility. (*Lars Andersen*, *Simrad*)
- ***Update on workshops***.
  - ICES broadband course/workshop/seminar on the "GO Sars". (*Egil Ona*, *Dezhang Chu*)
  - NOAA workshop. (*David Demer*)
  - Others?
- ***EK80 Evaluation*:** Ultimately a series of comparisons will need to be made between the EK80 and EK60, including running the EK80 in CW mode; comparing individual standard frequencies extracted from running the EK80 in FM mode (e.g. extracting the 38 kHz component from FM data); and assessing the additional benefits of the FM data. Cooperation within the community on these tests would maximize efficiency of effort.
  - Split-beam data – Marian Peña
  - Blue whiting data – Ben Scoulding
- ***ICES Working group*:** A new ICES working group focused on broadband methods seems appropriate. Also suggested was a working group examining the effects on marine mammals of active acoustic systems, both broadband and other. The terms of references of this new working group will be discussed at the WGFAST meeting in 2016 with the aim for the group to start in 2017 (if approved by ICES).

- ***Common test data (and code)*:** Test data, perhaps from standard targets and/or from real scatterers, should be made available for cross-comparison and verification of processing methods. This could be hosted on some kind of website. For those developers willing to share, code could be made available on the site as well. This would allow a standardization of methods (Egil Ona even suggested a certification process).
- ***Other topics*:** Group discussion**.**

Wideband Forum Report

An open forum, convened by Marian Peña, Mike Jech, and Ben Scoulding, was held on Tuesday of the WGFAST meeting to continue discussion of wideband acoustic technology and receive updates on technologies, workshops, and on-going developments. This forum follows the inaugural discussion that was convened following the close of the SOMEAcoustics symposium in 2015. Recommendations and suggestions from that discussion were used as a starting point for this forum.

We received an update from Simrad on the broadband EK80, which is the successor to the current standard scientific echosounder, the EK60. The current software version is 1.8.3, which was released in Feb.-March 2016. A new version, 1.9, will be released in the near future and will support more transceiver configurations and address various other improvements and other bug fixes. A new 38-kHz transducer, the ES38-7, will be released sometime in 2016. This will replace the ES38B and is designed to have a wider bandwidth (nominally 35-45 kHz). It will be a splitbeam configuration, but with 3 sectors rather than the traditional 4 quadrants, a center section with a wider beam width, and it will be depth rated. In addition to the ES38-7, new ES200-7CDK and ES333- 7CDK transducers are slated for development for broadband applications. A new 18- kHz transducer is in initial stages of development, but release is not expected for a few years. We also received an update from Echoview on their developments for wideband data processing. Echoview 7 provides updated support for wideband processing, and Echoview is preparing a white paper that will fully detail and define their processing algorithms and steps. Whether this should replace or supplement a Simrad manual or a paper published in a scientific journal was discussed.

An ICES-sponsored training course, "Principles and Methods of Broadband/Wideband Technologies: Application to Fisheries Acoustics" will be held on the G. O. Sars in Dec. 2016. Participation has already reached maximum numbers, with currently 4 on the waiting list. Course content was discussed and instructors will be Egil Ona, Gavin Macaulay, Rolf Korneliussen, Dezhang Chu, and Lars Andersen. Due to the popularity of this course, holding another course in the future was supported. In addition to the ICES training course, a NOAA-sponsored workshop is scheduled for Sept. 2016 in La Jolla, CA, USA. It is designed as a hands-on workshop with data collection in the NOAA Southwest Fisheries Science Center's large-tank facility and data processing. The workshop is limited to NOAA personnel, with 5 IMR and Simrad personnel attending. Preliminary comparisons of the Simrad EK80 and EK60 were presented by Marian Peña and discussed. Initial comparisons suggest overall similarities between the systems at 38, although there are some concerning differences at 120 kHz that were highlighted. More comparisons are certainly warranted. The time limit of one hour was reached without further discussion of other topics.

We recommend in the future that these forums continue, but manufacturer and commercial updates be held separately from the scientific forum, so that the community can discuss topics of interest. This is not intended to distance the industry as they are an integral component of moving forward with broadband technology and data processing. They will be invited and we hope they will attend the open forums, but with limited time and logistics, discussion of scientific issues should be a priority for these forums.