CMST News

June 2013

The Newsletter of the Centre for Marine Science & Technology

#20

Prof. Darlene Ketten wins Western Australian Fellowship

Prof. Darlene Ketten will relocate to Perth later this year as CMST's newest staff member. Darlene comes from two of the most reputable institutions in her fields of research: Harvard Medical School and Woods Hole Oceanographic Institution, both in the USA. She is the world's leading expert in biomedical imaging and 3D reconstruction of sensory systems in marine fauna, and in anthropogenic impacts on hearing. Darlene will establish a Functional Ocean Imaging Research Group within CMST. Her WA Fellowship, which is funded by the WA government, via the Department of Commerce, will focus on three themes: (continued on page 2)

PHOTO: DARLENE KETTEN

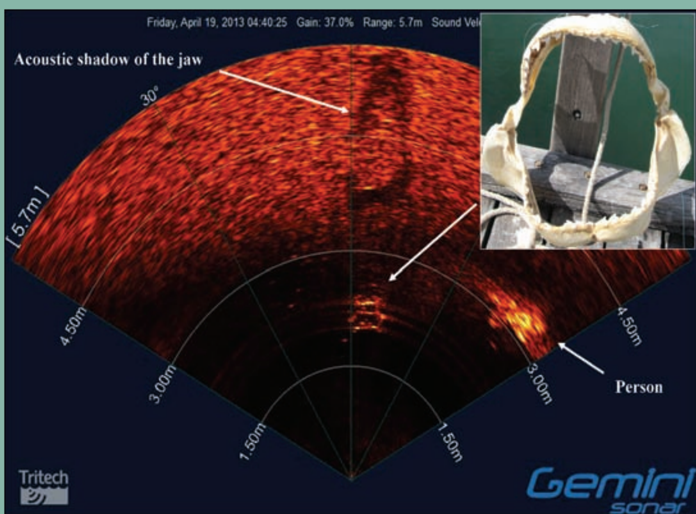
Darlene Ketten prepares a harbour porpoise for a CT scan.

Sonar imaging of large sharks

The recent increase in reported encounters between humans and sharks in Western Australia has prompted the Department of Commerce to launch the "Shark Hazard Mitigation" stream of the Applied Research Program, supported by the WA Government. In December, 2012, a collaboration led by CMST was awarded $273k to investigate "Sonar Imaging of Large Sharks", as part of that program. The objective of the project is to investigate acoustic reflectance from sharks at different frequencies, and quantify the ranges at which sharks can be detected and identified with sonar imaging. The long-term plan is to facilitate the development of a monitoring system for use around Western Australia if the method is successful.

On 19th April, 2013, fieldwork began in earnest at Fremantle Sailing Club. Together with collaborators Kim Allen (Intellipulse) and Rich Rickett (Seatools Pty. Ltd.), the team took a cleaned jaw structure from a 3 m tiger shark (*Galeocerdo cuvier*; provided by the Department of Fisheries WA) into the water. Investigators Miles Parsons (right) and Kim Allen (left) suspended the 65 cm wide, 80 cm high jaw mid-water to perform acoustic target strength measurements in depths of between 2 and 3 m. Initial tests in the harbour, conducted by Rich Rickett and Iain Parnum using a Tritech, Gemini multi-beam imaging sonar, produced acoustic images and videos of the jaw structure at ranges of up to 15 m.

IMAGE: IAIN PARNUM AND MILES PARSONS



Acoustic image of a shark jaw structure at 2 m range, using a Tritech Gemini.

Acoustic backscatter from the jaw was also collected using CMST's Biosonics DX system at 38, 120 and 420 kHz at various ranges and orientations to estimate the frequency response. Further investigations are to be made into jaw structures of varying size, but also additional scatterers within the shark body such as the dorsal plate and liver. The next step in the study will be to image complete sharks along the east coast of Australia, using the Gemini and a number of other sonar systems.

PHOTO: MALCOLM PERRY

Investigators Kim Allen (left) and Miles Parsons (right) with the tiger shark jaw.

Prof. Ketten joins CMST

(cont. from page 1)

1. Biomechanical modelling of hearing in marine fauna (mammals, sharks, birds, turtles, crocodiles, invertebrates); 2. enhanced imaging techniques of sensory systems; 3. pathophysiology of strandings, especially hearing loss and head and neck trauma.

Her past work comprised macro to micro examinations of marine and land organisms, laboratory and field necropsies, and CT and MRI analyses of head and neck trauma and disease in humans. She was recently appointed a Fellow of the American Association for the Advancement of Science, in recognition of her outstanding contributions to science!

IMAGE: DARLENE KETTEN

Darlene in action, standing inside the head of a stranded baleen whale, removing its ears for detailed analysis

Cataloguing underwater noise from offshore industries

IMAGE: CHRISTINE ERBE

Cossack Pioneer FPSO

Australian offshore oil and gas producers have formed a Collaborative Environmental Research Initiative (CERI) to share data and fund research. CMST has recorded underwater noise of offshore operations for 20 years on behalf of industry, government, defence and NGOs. This data is being synthesised under the CERI umbrella to produce a catalogue of anthropogenic underwater noise. This data is useful for environmental impact assessments, e.g. for the modelling of noise footprints of future operations. Recordings of six Floating Production, Storage and Offloading (FPSO) vessels were recently combined to characterise underwater noise emissions. An FPSO is a ship-shaped vessel used by the offshore oil industry for the processing and storage of hydrocarbons. FPSOs are frequently moored in place for prolonged periods, gathering hydrocarbons from multiple subsea wells, through flow lines, into the riser at its bow. There are many different sources of noise on and about an FPSO, resulting in a highly variable noise emission spectrum in both time and space around the FPSO. CMST's noise study was recently published in the Journal of the Acoustical Society of America:

Erbe, C., McCauley, R., McPherson, C., and Gavrilov, A. (2013) "Underwater noise from offshore oil production vessels", J. Acoust. Soc. Am. 133(6): EL465-EL470. http://tinyurl.com/FPSOnoise

Underwater noise of personal watercraft (jetskis)

IMAGE: CHRISTINE ERBE

Three active personal watercraft off the Gold Coast, Queensland.

Jetskis, wave runners, sea-doos and water scooters, are small personal watercraft (PWC) that are common along our populated beaches and waterways. Christine Erbe recorded their underwater noise several years ago, but only recently managed to analyse the data as part of an effort to establish a catalogue of anthropogenic underwater noise. "It turns out that their underwater noise actually sounds quite pleasant to human ears, like buzzing bees", says Erbe. However, we do not know how marine animals perceive this noise. "It is interesting to follow the debate about aerial noise of PWCs, which is very annoying to humans." Around the globe, complaints about PWC noise are lodged all the time, but none of the complaints are 'successful', because regulations for noise emissions are written in terms of broadband energy decibel (dBA), and PWC consistently are quieter than motor boats and are below the legal limits. "However, it is clearly not the broadband decibel that is annoying to humans, but rather the modulation of the noise", explains Erbe. "This is because of PWC's high-pitched whine, rapid change in pitch due to ongoing speed and direction changes, repetitive smacking of hulls against the water, constant exiting and re-entering of the water and the tendency of operators to circle about the same location for extended periods of time." Underwater noise regulations aimed at protecting marine fauna are also written in terms of broadband energy decibel, but actual impact on marine animals might not correlate with this quantity either! Food for thought… The corresponding scientific article can be downloaded for free.

Erbe, C. (2013) "Underwater noise of small personal watercraft (jet skis)", J. Acoust. Soc. Am. 133(4): EL326-EL330. http://tinyurl.com/jetski-noise

CMST workshop on underwater noise - A success

In November 2012, CMST hosted a one-day workshop on underwater noise in Fremantle in conjunction with the Australian Acoustical Society's annual conference. The workshop was attended by over 70 domestic and international participants from academia, industry, government and the military. The day began with tutorials on underwater acoustics, the marine soundscape and noise impacts on marine animals, in order to create a common background for the audience. Contributed presentations by members of the audience followed, as well as whole-group discussions on noise regulation, marine fauna monitoring, and noise impacts. "The workshop was a great success", says Christine Erbe, one of the organisers of the day. "Feedback from the audience was very positive. Specifically the tutorials were well received. People asked us to organise such an event on a regular basis; and people who missed the event asked to be put onto a mailing list for future workshops." A technical report on the workshop was published in Acoustics Australia's special issue on underwater acoustics: Erbe, C. (2013) "Underwater passive acoustic monitoring & noise impacts on marine fauna—a workshop report"
Acoust. Aust. 41(1): 113-119.
http://tinyurl.com/acous-impacts

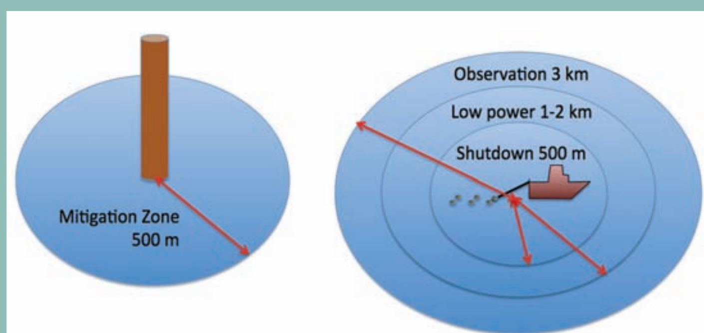
The success of November's Australian Acoustics Society conference sparked a special 'Underwater Acoustics' edition of the Acoustics Australia journal in April this year. The following pages offer a brief summary of the contributed papers that involved CMST authors. Topics include regulating noise, active and passive acoustic mapping of fish, and modelling transmission losses and signal distortion. Each of the papers are available for free download.

International regulation of underwater noise

Is the emission of underwater noise regulated? How? By whom? What is being done in countries other than Australia? – These are questions CMST staff are regularly asked. There is no simple answer. Most first-world countries have laws protecting marine life and many have guidelines or regulations for underwater noise. But these are dynamic and change over time, as results of new research become available.

Guidelines and regulations can be rather descriptive (as opposed to a do-not-exceed-threshold approach), and are interpreted and applied differently on a case-by-case basis considering not only the animals at risk, but also the specific operations, time-histories of cumulative exposures and practicality of several mitigation approaches. While specific guidelines and regulations differ from country to country, some commonalities exist relating to operational parameters, timing of operations, and mitigation requirements. In Australia, NOPSEMA regulates underwater noise from offshore oil & gas operations, while SEWPaC is broadly responsible for the protection of marine biodiversity. A review of international approaches to noise regulation, with examples and case studies, was recently published by CMST:
Erbe, C. (2013) "International regulation of underwater noise". Acoust. Aust. 41(1): 12-19. http://tinyurl.com/padd5we

IMAGE: CHRISTINE ERBE



Pile driving (left) and EPBC 2.1 Seismic (right) protocols for impacts on marine fauna

Curtin University

Modelling acoustic transmission loss due to sea ice cover

The propagation of underwater acoustic signals in polar regions is dominated by an upward refracting sound speed environment and the presence of a dynamic, highly variable ice canopy. CMST's PhD student Polly Alexander recently provided an overview of the acoustic properties of sea ice and assessed the influence of ice canopy and water column properties on acoustic transmission loss in the 9-12 kHz frequency band between a ship and an autonomous underwater vehicle (AUV) operating within a 20 km radius of the ship.

The influence of the ice canopy was assessed first as a flat surface, and then as a statistically rough surface via a Monte Carlo method. A typical set of ice statistics was evaluated using Ray and Beam acoustic propagation techniques. The sound speed profile (based on real data) resulted in strong defocussing of direct path signals at ranges from 9-20 km and depths shallower than 50 m. This reduction in the signal strength of the direct path created areas where the influence of surface reflected paths became significant. The inclusion of a perfectly flat ice layer reduced the transmission loss between 9-20 km by 15-50 dB. When the ice layer was included as a rough surface layer, the results showed a boost to signal strength of up to 8 dB in the small areas of maximum defocussing.

Sea ice is a strongly time and space varying sea surface and exists in areas where defocussing of the direct path due to the sound speed profile reduces the range of direct path dominated transmission. Polly's paper presents methods to include a statistically relevant rough surface through a technique for generation of sets of surfaces based on ice deformation statistics. It outlines methods for including ice in acoustic modelling tools and demonstrates the influence of one set of ice statistics on transmission loss. Acoust. Aus. 41 (1) 79:87 http://tinyurl.com/acoustic-sea-ice-losses

PHOTO: AUSTRALIAN ANTARCTIC DIVISION ROV TEAM

View of Antarctic sea ice from below taken by an ROV.

Sounds of fish off Cape Naturaliste

Around Australia numerous species of fish produce sound, individually, in small groups, or as part of a chorus, and their calls contribute considerable energy to the underwater soundscapes. There are many fish species of social and economic importance which could be the source of these sounds and an increasing number are being studied to confirm if they are soniferous. For example, captured West Australian dhufish (*Glaucosoma hebraicum*), a species which is endemic to the Western Australian coast, have been shown to produce calls comprising trains of swimbladder pulses. Similar calls have also now been detected at artificial reefs, known to be home to juvenile WA dhufish, off Albany in state's southwest illustrating that the species also calls *in situ*. Further investigation is being conducted to determine whether passive acoustic techniques can be used to detect presence of the species in a given area.

Over the past few years CMST has collected several datasets from waters around Cape Naturaliste, a location where some of the largest numbers of WA dhufish are reported. Dr. Miles Parsons has recently described the characteristics of sounds produced by soniferous fish in the area. Five fish choruses were detected, centred at approximately 0.5, 1, 2 and >2 kHz (two choruses at >2 kHz). Many individual fish calls have now been detected at various locations around the Cape, particularly in the frequency ranges between 100 and 900 Hz, with some displaying characteristics similar to those recorded from captive dhufish off Rottnest Island in 2011.

This work has been conducted as part of a Fisheries Research and Development Corporation funded project, and the work in the southwest was conducted with significant support from the Department of Fisheries and Sea Rescue. Acoust. Aus. 41 (1) 58:64 http://tinyurl.com/wa-fish-choruses

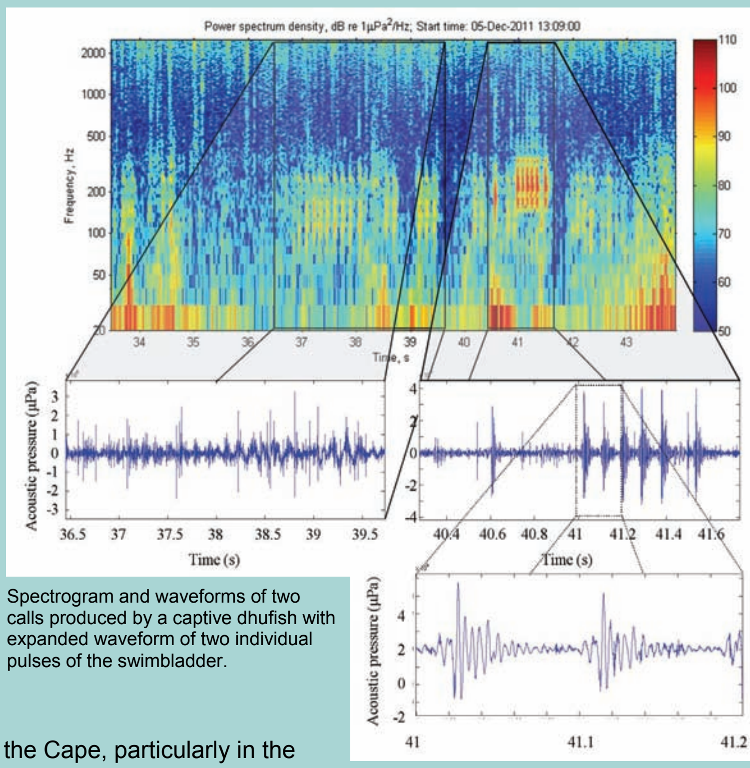


IMAGE: MILES PARSONS

Spectrogram and waveforms of two calls produced by a captive dhufish with expanded waveform of two individual pulses of the swimbladder.

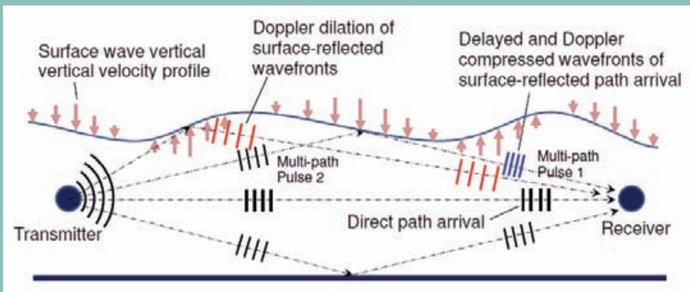


FIGURE: MICHAEL CALEY

Conceptual signal Doppler shift and path delay.

Simulation of acoustic communication signal distortion

The underwater acoustic communication environment is highly reverberant, resulting in multiple reflected copies of any transmitted signal arriving at the receiver at delayed intervals (delay spreading), and with the relative delays changing dynamically. The frequency of transmitted signals is also significantly distorted by transient Doppler effects generated by elongation and contraction of surface reflected transmission paths (Doppler frequency spreading), or Doppler frequency shifts from movement of either (or both) the transmitter and receiver. These transient distortions present significant challenges to signal decoding by a communications receiver.

In 2011 CMST and the Curtin Department of Electrical and Computer Engineering commenced a project to develop high-rate underwater acoustic communications to support developing ocean-based industries in Australia. CMST has undertaken acoustic channel probing trials in 14 m and 50 m deep environments, is developing an underwater acoustic communication channel simulator to support this project.

The purpose of the simulator is to model the way that the real ocean produces transient distortion of acoustic communication signals between a transmitter and a receiver. The simulator will provide a configurable analogue of the real ocean that can be used to improve understanding of the influence of the marine acoustic environment on communications signals, and assist the development of underwater communication modulation and demodulation algorithms and hardware. Transient phenomena that are key to the development of an acoustic channel simulator for high-rate data communications are the transient delay and Doppler frequency spreading of the received signal imparted by the moving sea-surface.

Acoust. Aus. 41 (1) 20:28
http://tinyurl.com/doppler3

Ensonifying schools with sonar

Multi-beam sonar (MBS) systems offer the ability to ensonify an entire school of fish in a single pass. As part of a Fisheries Research and Development Corporation funded project CMST investigated the acoustic backscatter from the seafloor and water column, collected with Reson 7125 and 8125 MBS systems. In particular, data from Department of Fisheries surveys of aggregations of Samsonfish (Seriola hippos) off Rottnest Island were analysed.

Part of the study focussed on the ability to visualise the backscatter from different seafloor habitat types and water column fauna collected from individual transects (right) and movement of a school, while another looked at changes in structure of fish schools over time (left) and discerning individual fish.

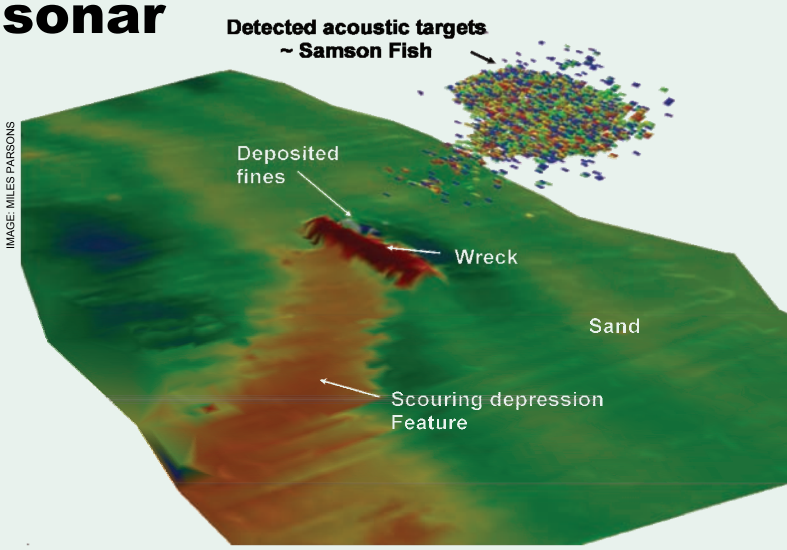


IMAGE: MILES PARSONS

Aggregation of Samsonfish and the habitat over which they school, as detected by a Reson 7125 multi-beam sonar.

Plan views of a Samsonfish (red volume) and skipjack trevally (yellow volume) school over time, as detected by a Reson 8125 multi-beam sonar.

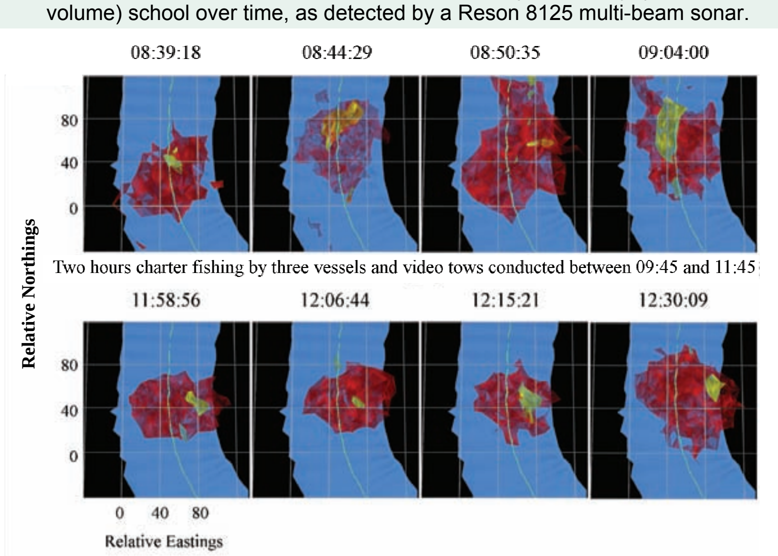


IMAGE: MILES PARSONS

In certain circumstances individual fish can be resolved as acoustic targets (either as a single fish within a sample, or as a cluster of samples that delineate a single fish), and in these cases the fish packing density may be analogous to the acoustic packing density. The results highlighted the ability of MBS to detect different fish packing densities, but also that packing density within schools of the same species is dependent on behaviour at the time of survey, often affected by vessel presence.

ICES Jour. Mar. Sci. 70 665:674
http://tinyurl.com/acoustic-fish-visualise
Acoust. Aus. 41 (1) 107:112
http://tinyurl.com/fishpacking

Curtin University

GUMSTIX – Powerful, but not so tasty!

CMST PhD student Michael Bittle is investigating the real-time processing of audio signals using very small, low-power embedded computer systems. These ‘Computers-on-Modules’, or COMs, are small enough to be placed inside of a hydrophone housing, plus their power requirements are low enough that small batteries alone can provide many days of running time. Current development is focused on the GUMSTIX range of COMs. These COMs are the size of a stick of chewing gum and yet are very powerful and packed with peripherals, a digital signal processor, USB hosting capability, and even 3D graphics capabilities.

Development at this stage has focused on running a Linux environment on the system and building the foundations for the reliable processing of audio. Under the guidance of Dr. Alec Duncan the system is being profiled and its performance limits are being established. This device will be used as a major component in Michael’s ongoing PhD study which is concentrated on developing systems for real-time passive acoustic monitoring of marine mammals, including detection and classification.

Development plans for the future involve demonstrating the system’s function with a single marine mammal species and then expanding to a variety of species, initially using existing recordings, but with the goal to deploy and test in the ocean at later stages.

IMAGE: MICHAEL BITTLE

The tiny GUMSTIX Overo Water COM

Government Grant to Support 3D Imaging of HMAS Sydney II and HSK Kormoran wrecks

The Australian Commonwealth Government recently announced the award of a $483k *Your Community Heritage* grant to support the use high-resolution 3D imaging technologies to survey the wrecks of the HMAS Sydney II and the HSK Kormoran. The project will allow the site to be properly protected, conserved and interpreted for future generations. At Curtin, the project is led by Andrew Hutchison from Design, Andrew Woods from CMST, and Petra Helmholz from Spatial Sciences. “For the past two years we have been conducting research on the image and video dataset that was collected from the wreck sites when they were discovered in 2008 – both to understand the site and to test new 3D imaging technologies for a future return to the wrecks. The small selection of 3D images and 3D models we have extracted so far are stunning and illustrate the great potential for improving the understanding and interpretation of deep-water wrecks,” explained Woods. The project is a collaboration between Curtin University, WA Museum, DOF Subsea, Australian National Maritime Museum, iVEC@UWA, and several other project partners. The first research paper from the project was recently presented in Germany: http://tinyurl.com/3d-structures

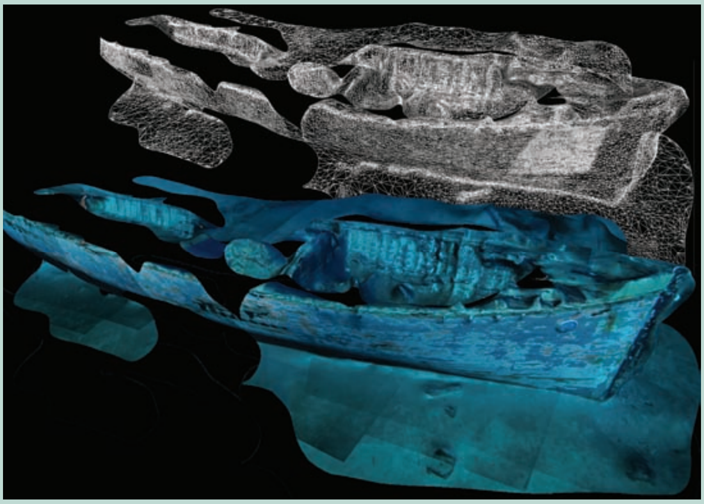


IMAGE: GRACE BEVEN, ANDREW WOODS, ANDREW HUTCHISON, PAUL BOURKE. DERIVED FROM 2D IMAGES © 2008 AUSTRALIAN WAR MEMORIAL VIA THE FINDING SYDNEY FOUNDATION. UNDERWATER SEARCH PHOTOGRAPHY BY DAVID MEARNS.

A 3D reconstruction of one of the ship’s boats of the HMAS Sydney II with wireframe representation in the background.

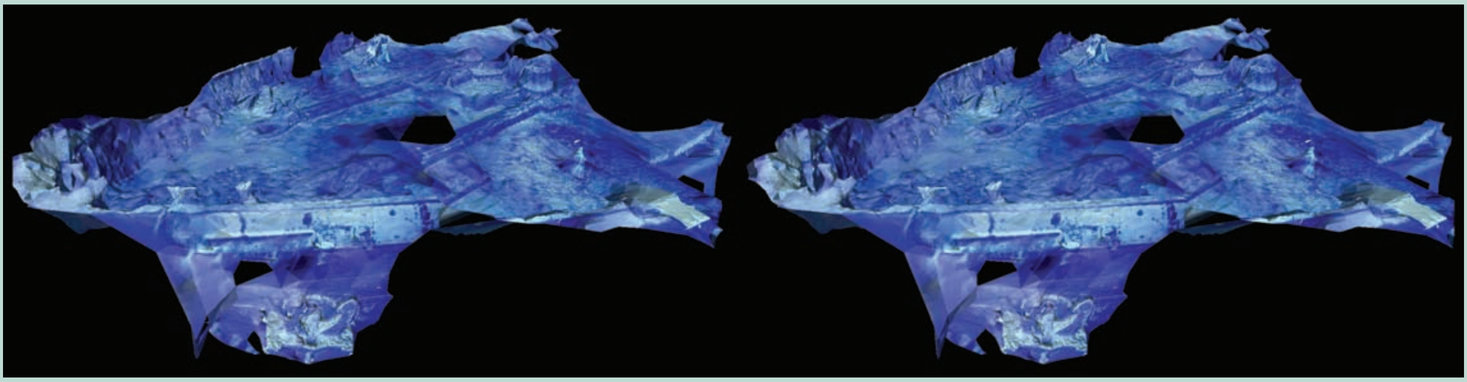


IMAGE: JOSH HOLLICK, ANDREW WOODS, SIMON MONCRIEFF, DAVID BELTON, ANDREW HUTCHISON, PETRA HELMHOLZ. DERIVED FROM 2D IMAGES © 2008 AUSTRALIAN WAR MEMORIAL VIA THE FINDING SYDNEY FOUNDATION. UNDERWATER SEARCH PHOTOGRAPHY BY DAVID MEARNS.

A stereoscopic image of a 3D reconstruction of the foredeck of the wreck of the HSK Kormoran. Visible in the image is the vessel’s anchor (bottom) and anchor chains across the foredeck. This image is a cross-view stereoscopic image pair and can be seen in 3D by cross-fusing the two images. Cross-fuse stereoscopic viewing instructions are available at: http://www.starosta.com/3dshowcase/ihelp.html

Integration of acoustical, physical and biological oceanography

As wind blows over the ocean, underwater noise is generated. The spreading of this noise through the ocean depends on physical oceanographic features, such as temperature and salinity. Sea-noise loggers record the spectrum of this noise, from which physical oceanographic quantities can be inferred. In addition, currents flowing around the recorder generate typical flow noise, which correlates with current speed. Physical oceanographic parameters also determine the presence of marine life from small invertebrates, to fish and large whales. Most of these animals produce sounds, which are also recorded. Acoustical, physical and biological oceanography are intricately linked, to the point where one or two can predict the other(s); however, data correlations are rarely examined.

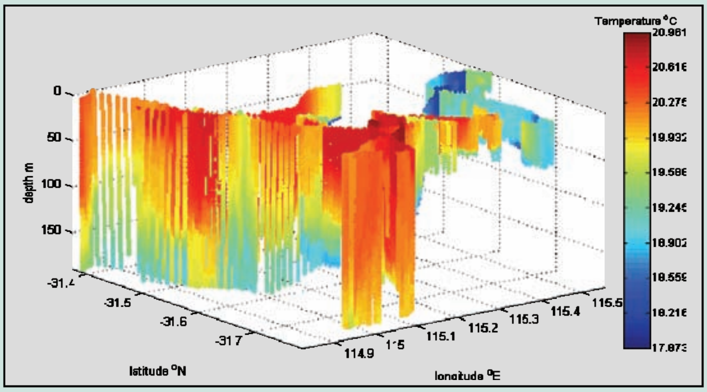
IMAGE: MARTA GALINDA ROMERO

Arti Verma

This is the research Arti Verma has chosen. She joined CMST in November 2012. She is working on physical, acoustical and biological data collected by the Integrated Marine Observing System (IMOS). Currently, she is trying to correlate the noise spectrum recorded by CMST's noise loggers with physical oceanographic quantities like winds, currents, temperature and salinity.

Prior to joining CMST, Arti was a research fellow at the Birla Institute of Technology, in Ranchi, India, where she worked on nonlinear propagation of optic waves in quantum well and quantum dot structures. Arti has strong physics and mathematics skills and is being supervised by Christine Erbe, Rob McCauley and Sasha Gavrilov.

IMAGE: ARTI VERMA



Variation of temperature with depth recorded by the IMOS Slocum glider in the Perth Canyon (30th July 2010 – 22nd August 2010)

Prediction of the peak pressure of man -made impulsive noise in the ocean

Acoustic peak pressure and sound exposure level of an impulsive signal are the major parameters used to determine potential impacts of man-made impulsive underwater noise on marine fauna, as reflected in the latest regulations and policies focussed on the protection of the marine environment. When the acoustic propagation environment is known, existing numerical models can predict transmission loss of the energy, and consequently the spatial decay of the sound exposure level, with sufficient accuracy for this purpose. However, predicting the peak pressure and its variations is still a problem.

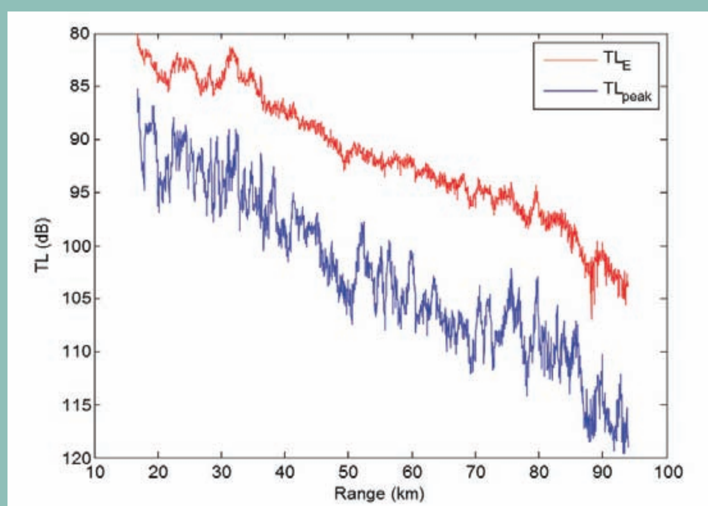
As part of her PhD at CMST, supported by a Chevron scholarship, Marta Galindo Romero is investigating the propagation of acoustic peak pressure through the ocean. Using field measurements of received peak pressure and energy of impulsive airgun signals in a range-dependent environment over the continental slope off Cape Leeuwin in Western Australia, Marta has been testing conventional numerical models to predict the effects of spreading and scattering on the propagation of peak pressure. Marta is hoping both to improve numerical models for peak pressure propagation as well as to derive empirical relationships, with the ultimate goal of increasing our ability to estimate potential bioacoustic impacts on marine fauna.

In 2010, Marta obtained her BSc. from the University of Murcia, Spain, and spent her final year at Birmingham University, UK, having been awarded an Erasmus grant. She was also awarded a fellowship at a Naval and Marine Technology Centre in Spain that year and at the same time commenced a Master's in Information and Communication Technologies at the Technical University of Cartagena, Spain, completing it in 2011.

IMAGE: MARTA GALINDA ROMERO

Marta Galinda Romero

IMAGE: MARTA GALINDA ROMERO



Experimental transmission loss of peak pressure and sound exposure over the continental slope off Cape Leeuwin, Western Australia.

Curtin University

Ship squat benchmarking workshop

CMST has been invited to put in a submission to the 2013 ship squat benchmarking workshop in Duisburg, Germany. This is a blind validation trial for ship under-keel clearance software from around the world. A 9 m model containership hull has been extensively tested in the Duisburg towing tank, and these experimental results will be used for the blind validation.

CMST's results will be calculated using "ShallowFlow", our in-house software for modelling flow around a ship in a channel with arbitrary transverse bathymetry.

The workshop will take place in September, at which time results from all codes, together with the experimental results, will be published.

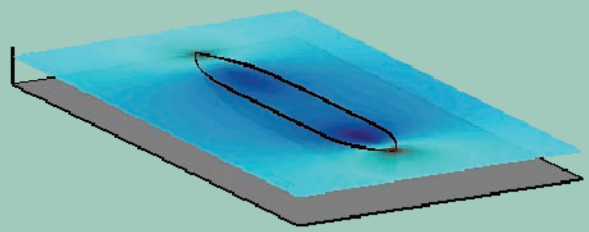


IMAGE: TIM GOURLAY

Hydrodynamic pressure field around a Japanese standard series bulk carrier, calculated using ShallowFlow software.

High-speed marine echolocation click detector

Accurate automated detection and identification of underwater biological sounds is an ever-present goal for many marine biologists and a number of different methods have been applied to each type of acoustic signal. One method is the Teager-Kaiser Energy Operator (TKEO) used by several bioacousticians to detect echolocation clicks of marine animals. In 1946, Dennis Gabor proposed to apply the ideas from quantum physics to sound, allowing an analogy between sound and quanta, and since then research has shown that underwater echolocation clicks of several species can be modelled as Gabor functions.

At CMST, PhD candidate Shyam Madhusudhara has been developing a click detector for Gabor-type underwater echolocation clicks of odontocetes and cetaceans after evaluating the application of TKEO to discrete Gabor signals. He has determined that the TKEO output on these signals can be approximated by a Gaussian function. Real-time application of two different filters (one Gaussian and one rectangular) to the TKEO output has shown that the ratio of outputs from the two filters is an effective detector. Not only that, but this ratio is more robust to changing noise conditions and low signal-to-noise ratios than if an absolute threshold were applied directly to the TKEO output.

Shyam has discovered that, with its low computational complexity, this method operates thousands of times quicker than real-time over a range of scenarios. He has also been comparing the methods to case studies containing known odontocete echolocation clicks, with promising results.

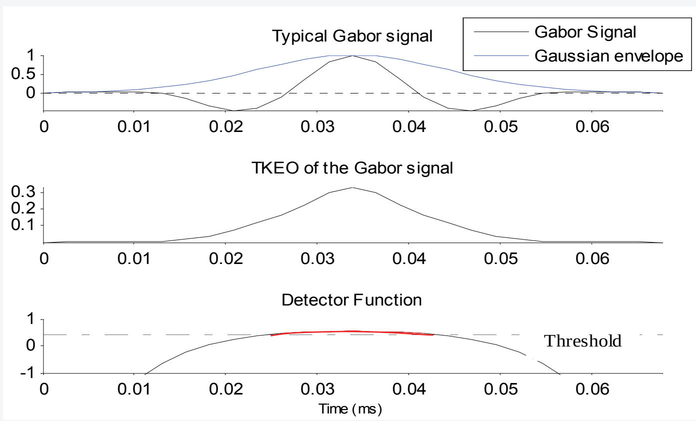


IMAGE: SHYAM MADHADSURA

Performance of difference methods to detect an echolocation click.

Introduction to naval architecture online course

From July 2013, CMST will be offering an online "Introduction to Naval Architecture" unit. This is based on our engineering-elective "Design for Small Craft" unit, which has been taught since 1990. The unit focuses on CMST's specialty area of ship hydrodynamics.

Topics include lines plans, form coefficients, stability, motions in waves, resistance, propulsion, sail theory and a Maxsurf design project.

Please contact CMST for further information or to register your interest.

CMST Lunchbox Seminars

CMST holds weekly seminars, with speakers from interstate and overseas, as well as CMST staff.

The schedule of seminars is listed on our website:
www.cmst.curtin.edu.au/seminars

If you would like to receive email updates regarding CMST seminars, simply send an email to the following address:
seminars@cmst.curtin.edu.au

The Centre for Marine Science & Technology (CMST) conducts world-class consulting, research, development and education for the marine industry and for government agencies.

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