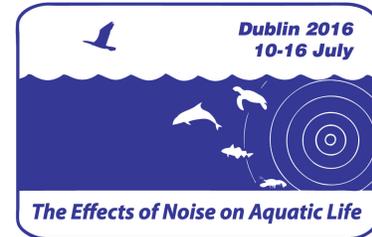




## Fourth International Conference on the Effects of Noise on Aquatic Life

Dublin, Ireland  
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## Overview of the Fourth International Conference on the Effects of Noise on Aquatic Life

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*The Effects of Noise on Aquatic Life* is an international conference series that was started by Arthur N. Popper and Anthony D. Hawkins in Nyborg, Denmark, in 2007. Volume 27 of *POMA* brings together articles based on many of the presentations at the fourth conference that took place in Dublin, Ireland, 2016. Underwater noise from pile driving, seismic surveying, shipping, but also non-anthropogenic sources such as wind was examined. The potential effects on animals ranging from plankton, shrimps and crabs, to lobsters, fishes, seals, dolphins, and whales were discussed. Reported effects include behavioral responses, auditory masking, cardiac rate changes, stress, a temporary loss of hearing, and perhaps more serious tissue and organ damage. Short-term and long-term, individual and population-level effects were portrayed. Several studies also looked at the fundamentals of animal sound production and perception. One session dealt with the regulation and management of underwater noise. The social program was intended to encourage more leisurely discussions amongst conference participants in order to facilitate networking and the strengthening of relationships. The feedback from conference delegates (submitted via an online survey after the meeting) was very positive.



## 1. INTRODUCTION

*The Effects of Noise on Aquatic Life* is a topic of growing international concern and research. Underwater noise originates from marine traffic, port construction, offshore petroleum and mineral exploration and production, marine renewable energy plants, fisheries, defense operations, surveying, and scientific research, etc. The potential impacts on marine life range from none or mere detectability of associated sound, to acoustic masking, behavioral responses, stress, temporary hearing loss, and more severe physical and physiological effects such as organ and tissue injury that may lead to death.

Arthur N. Popper and Anthony D. Hawkins initiated a conference series on the effects of noise on aquatic life and the inaugural meeting was held in Nyborg, Denmark in 2007 (Hawkins *et al.*, 2008). This was followed with meetings in Cork, Ireland in 2010 (Popper and Hawkins, 2012), and then Budapest, Hungary in 2013 (Popper and Hawkins, 2016). The fourth meeting in the series took place in Dublin, Ireland in 2016. Dublin was selected since the Irish marine science and marine industries are strong and because Dublin is easily accessible from anywhere in the world. Dublin also provided ample opportunities for evening outings at the end of a busy day at the conference, daytime activities for accompanying persons, and vacation destinations for families.

This conference series continues to bring together scientists, regulators, environmentalist and industry representatives to learn about and discuss the potential effects of man-made noise on aquatic organisms. Emphasis is on cross-fertilization of ideas and findings across species and noise sources. This kind of sharing of material is of exceptional value since there are many commonalities in issues that never get appreciated except at meetings that cross disciplines and ideas. Participants learn about matters that they normally do not encounter. For example, scientists learn about the concerns of regulators, while industry representatives learn about the latest data, etc.

The number of participants at the conferences has been steadily growing. There were 202 delegates and 134 presentations in Nyborg; 244 delegates from 22 countries and 111 presentations in Cork; 243 delegates from 24 countries and 125 presentations in Budapest; and 323 delegates from 23 countries and 229 presentations in Dublin. Indeed, it was necessary to limit the number of registrations in Dublin and to keep a waiting list as the venue was reaching capacity.

This POMA volume contains articles based on many of the papers presented at the Dublin meeting. Submission to POMA was not a requirement for presenting unless presenters received any funding from the conference to attend. Almost 100 people, including all students and postdocs who requested support, received it thanks to generous funders (see Acknowledgements).

## 2. SCIENTIFIC SESSIONS

Presentations were a mixture of 15-minute oral presentations, 4-minute speed talks, and posters. Each speed talk presented the highlights of an accompanying poster of the same title. There were also three 40-minute keynote presentations. The following sections give brief summaries of oral and poster presentations by themes.

## A. KEYNOTE PRESENTATIONS

William Yost (Arizona State University, USA) gave a keynote presentation on human auditory perception and noise impacts, primarily masking. His basic introduction to human psycho- and neuroacoustics provided the foundation for much of the animal research we heard about during the week. His overview of data on humans also made us realize how little we still understand about hearing in marine fauna.

Enda Murphy (University College Dublin, Ireland) gave a keynote presentation on terrestrial noise, its impacts on humans, and mitigation and regulation. Noise leads to a disease burden second in magnitude to air pollution, with 1.6M life years lost per year in the western European Union. Common metrics of noise exposure are poor predictors of impact, and a consistent approach to exposure measurement and mapping is lacking. We saw many parallels to the underwater world.

Daniel Owen (Fenners Chambers, UK) gave the third keynote presentation, which was on the regulatory and legal framework of underwater noise, focusing on shipping and exploration of mineral resources.

## B. SOUNDSCAPES

There were several talks and posters on marine soundscapes from various geographic regions. Short- and long-term datasets were presented and spatio-temporal patterns and variation were discussed. The sources of sounds in the various soundscapes were described, and we learned about crustacean, fish, and mammal behavior and ecology based on passive acoustic data. A common tool was sound mapping, in particular of ship noise, such as in the North Sea and the Arctic. Finally, acoustic indices calculated from soundscape recordings were portrayed in relation to ecosystem parameters and biodiversity.

## C. UNDERWATER ACOUSTICS

A number of presentations focused on the theoretical aspects of underwater acoustics, and how these need to be considered during the design of experiments—whether in tanks or in the field. The modeling of noise and vibration, sound generation, and propagation were elements of several talks and posters. Predicting and measuring acoustic fields is particularly complicated in enclosures such as pools and tanks due to multiple reflections, standing waves, and resonances, all of which are affected by the acoustic properties of the boundaries (i.e., walls, floor, and surface). Acoustic quantities such as particle displacement, velocity, and acceleration need to be considered in experiments with animals that can detect particle motion. Last but not least, the standardization of acoustic terminology, sound measurement, and reporting has become an urgent need.

## D. EFFECTS OF NOISE

Being the main theme of the conference, most presentations fell into this category. We learned about sound production and reception in various taxa, and the effects of noise on both processes. The Lombard Effect was demonstrated in fishes and marine mammals, and involves an alteration of the characteristics of sounds produced by animals in the presence of noise. Masking, the interference of noise with sound detection, was discussed for a number of species as well. Many studies reported behavioral responses of animals to sound. Physiological responses, such as increased heart rate and stress, were quantified, as was noise-induced hearing loss. Some presenters took us from noise effects on individuals to entire populations, based on

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novel modeling approaches. It was also interesting to see a few presentations on the lack of measurable responses to noise.

## **E. REGULATION**

Talks and posters under this theme introduced regulation and management of noisy activities in different countries, such as the Marine Strategy Framework Directive of the European Union and the new NOAA guidelines on assessing noise impacts. Specific noise sources covered included naval sonar, pile driving and seismic surveying. Various mitigation measures and results from studies of their effectiveness were presented as well, such as the implementation of mitigation zones, the effectiveness of ramping up the source, the use of deterrence signals, and experiments with warning sounds that lead to a brief reduction in hearing sensitivity in some animals.

## **3. RODNEY COATES AWARD**

At this year's conference, an award for the best student presentation was given in honor of the late Rodney Coates. Through the generosity of Rodney's wife Gillian Coates and her children Damion and Shana, a first-place prize of 1,000 GBP was awarded for the best student presentation and an additional Coates family donation was provided so that similar awards can be given at subsequent conferences. With help from the conference sponsors, the organizing committee was pleased to announce at the conference additional awards of a second-place prize of 500 GBP and a third-place prize of 250 GBP.

Rodney Coates attended several of the previous Effects of Noise on Aquatic Life conferences and was avidly interested in this area of research. Following his retirement, Rodney started a company that specialized in the education of underwater acoustics.

It is the hope of the Coates family that the endowed Coates award will be given to those young researchers who have developed not only an understanding of their subject but also an ability to communicate their work to others of all backgrounds.

Twenty-six students participated in the competition with each giving a 4-min speed talk followed by a poster presentation the next day. The competition was evaluated by eight judges who were members of the advisory and organizing committees: Mathias Andersson, Ronald Kastelein, Nathan Merchant, Stephanie Plön, Kathy Vigness-Raposa, Amy Scholik-Schlomer, Christine Erbe and Joseph Sisneros.

The winners were:

1st prize - Caroline Casey (University of California Santa Cruz, CA, USA) "Source-Level Estimates for Harbor Seals and Implications for Estimating Communication Space."

2nd prize - Line Hermannsen (Aarhus University, Aarhus, Denmark) "The Missing Noise Metric: Small Boats Without an Automatic Identification System Contribute Considerable Noise to Marine Coastal Areas."

3rd prize - Maxwell Kaplan (MIT-Woods Hole Oceanographic Institution, Woods Hole, MA, USA) "Temporal and Spatial Variability in Biological Sound Production on Tropical Coral Reefs Is Linked to Biota."

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## 4. SOCIAL PROGRAM

On Sunday night before the conference, a welcome reception was held in the ballroom of the Davenport Hotel. A hot and cold buffet dinner was served, accompanied by live Irish music and Irish step dance performances.

The conference opened on Monday morning with live music by Irish harpist and singer, Deirdre Seaver (<http://www.deirdreseaver.com>) to get the participants “in the mood” for the meeting. Every conference participant received a hand-signed CD by Ms. Seaver as a souvenir in their conference bag.

On Tuesday, a public evening was held to which the wider Dublin community was invited. James Miller (University of Rhode Island, USA) explained the basics of acoustics and got the whole audience involved in a hearing test. Anthony Hawkins (Loughine Ltd., Scotland) took us on an acoustic journey into the Irish underwater soundscape. Rebecca Dunlop (University of Queensland, Australia) presented behavioral response studies with humpback whales, and Darlene Ketten (National Academy of Sciences, USA) taught us about hearing and hearing impairment in marine animals. We had called for submissions of short (3-min) films about underwater noise and its potential impacts on marine life prior to the conference and four films were shown on Tuesday night in between lectures.

After the first two full days of the technical program, a 5 km fun run and a 1 km walk through downtown Dublin and along the Liffey River were held on Wednesday morning. Blue skies and sunshine were enjoyed by nearly 100 runners and walkers.

On Thursday night, a DJ played international music at Oscar’s Bar in the Mont Clare Hotel. Nearly 150 conference participants and partners attended, and a few dozen danced into the early morning hours.

Friday evening was the conference dinner in the Dining Hall at Trinity College. The evening began with a private viewing of the renowned Celtic manuscript, the Book of Kells, followed by a reception with wine and canapés inside the magnificent Trinity College Library. We then walked over to the Trinity College dining hall for dinner, and enjoyed Deirdre Seaver once more playing the Irish harp and singing traditional Irish songs.

## 5. PARTICIPANT FEEDBACK

An online survey was set up at the end of the conference and 189 participants (60%) responded within two weeks. The age distribution of the meeting (Table 1) shows that almost 50% of the participants were under 40 years of age, suggesting that there is an increasing number of younger people interested in the topic of the meeting.

About 28% of participants were graduate students and postdocs, and another 24% university faculty (Table 2), meaning that almost half of the participants represented other stakeholders. This is of particular importance since one of the major purposes of the meeting is to bring together people from various backgrounds and employment sectors to discuss issues of underwater noise. Also, 23 countries were represented at the meeting (Table 3).

There was general satisfaction with the overall meeting (Table 4). The major criticism regarded the poster space, which was too small due to an unanticipated number of submitted abstracts. People very much liked the talks and particularly the speed talks, as well as our opportunity to present awards to the best student papers (Coates Award). Participants quite

uniformly appreciated that we did not have parallel sessions. And, most importantly, people commented on the exceptional opportunities for conversations and networking.

**Table 1. Age distribution of participants**

Answer Options	Response Percent	Response Count
Under 30	17.8%	33
30-40	30.8%	57
41-50	23.8%	44
51-60	18.9%	35
>60	8.6%	16
<i>answered question</i>		185
<i>skipped question</i>		4

**Table 2. Professional sector of participants**

Answer Options	Response Percent	Response Count
Undergraduate	0.6%	1
Graduate student	14.1%	25
Postdoc	13.6%	24
University faculty	24.3%	43
Industry	7.9%	14
Regulator	6.2%	11
Environmental group	1.1%	2
Consultant	16.9%	30
Government (non-regulatory)	15.3%	27
Other (please specify)		15
<i>answered question</i>		177
<i>skipped question</i>		12

**Table 3. Countries of participants. Other countries listed were Belgium, Brazil, Croatia, Estonia, Greece, Portugal, South Africa, and Taiwan.**

Table 3: Country		
Answer Options	Response Percent	Response Count
Australia	5.7%	10
Canada	8.0%	14
Denmark	2.3%	4
France	2.9%	5
Italy	3.4%	6
Germany	4.0%	7
China	0.6%	1
Ireland	4.0%	7
Netherlands	6.3%	11
New Zealand	2.3%	4
Norway	1.1%	2
Poland	1.1%	2
Spain	2.9%	5
United Kingdom	10.9%	19
United States	44.3%	77
Other (please specify)		14
<i>answered question</i>		174
<i>skipped question</i>		15

**Table 4. Participants' opinions about different aspects of the meeting (1: greatly disliked, 2: disliked, 3: neutral, 4: liked, 5: greatly liked). Table shows votes as per cent of all responses to each question.**

Answer Options	1	2	3	4	5	Response Count
Poster space	23.4%	33.5%	23.9%	15.4%	3.7%	188
Poster organization	6.9%	9.6%	26.6%	42.0%	14.9%	188
Poster quality	1.1%	2.7%	13.3%	51.6%	31.4%	188
Meeting (lecture) room	3.2%	12.7%	24.3%	39.7%	20.1%	189
Dublin as a meeting venue	1.1%	2.1%	13.8%	27.0%	56.1%	189
Meeting web site	1.1%	2.7%	17.2%	48.9%	30.1%	186
Meeting registration (and its ease of use)	1.6%	3.2%	9.6%	38.3%	47.3%	188
Information provided prior to the meeting	1.1%	2.1%	8.5%	42.9%	45.5%	189
Lightening rounds (speed talks)	1.6%	0.5%	6.9%	41.0%	50.0%	188
Time for discussion after groups of papers	2.7%	11.3%	15.6%	46.8%	23.7%	186
Coates Award	0.0%	1.8%	14.1%	38.2%	45.9%	170
<i>answered question</i>						189

## 6. CONCLUSION

At the five-day conference in Dublin we heard about new research on the effects of noise on marine fauna, and sometimes the lack of effects. Our understanding of potential impacts is steadily growing. More and more sources of noise are being investigated, and more and more animal species are being studied. We are well on our way to assess the potential effects on marine ecosystems. Many sound monitoring projects have been going on for years now, and we are beginning to be able to look at long-term effects.

In Dublin, we had the opportunity to discuss underwater noise and its potential impacts with fellow scientists, government representatives and regulators, industry representatives, defense staff, and members of non-government organizations. Some presentations (in particular those by Enda Murphy, Daniel Owen and Jill Lewandowski) pointed out communication problems between stakeholders—not just hurdles, but real barriers at times. We have all had different pathways into the field of underwater noise impacts, and we all have different expectations and motivations. It is through conferences like this one, that we grow our understanding of each other's concerns and needs, and have an opportunity to build relationships and grow as a community.

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## ACKNOWLEDGMENTS

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Our media committee, consisting of Marta Bolgan (Marine and Freshwater Research Centre, GMIT, Ireland), Ashwin Bhandiwad (National Institute of Child Health and Human Development, NIH, USA), and Sarah Marley (Curtin University, Australia), organized the public lecture night and kept the community up-to-date via Facebook and Twitter.

Jenni Stanley, Louise Roberts, and Jamie McWilliam helped in Dublin passing around microphones during discussion sessions and taking photographs.

Patty Doerfler (University of Maryland, USA) handled much of the grant income and all of the finance reimbursements on our behalf.

Last but not least, we thank Terri Cullinane of VenuesWorld for her expert help with all conference logistics, venue, hotels, social functions, registration, website, lunches and coffee breaks. This was the third of these meetings that Terri and her colleagues organized and much of the non-scientific success of the meeting goes to the outstanding and thoughtful work of this group.

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## REFERENCES

- Hawkins, A. D., Popper, A. N., and Wahlberg, M. (2008). "Introduction: International Conference on the Effects of Noise on Aquatic Life," *Bioacoustics* **17**, 1-3.
- Popper, A. N., and Hawkins, A. D. (2012). *The Effects of Noise on Aquatic Life* (Springer Science+Business Media, New York).
- Popper, A. N., and Hawkins, A. D. (2016). *The Effects of Noise on Aquatic Life, II* (Springer Science+Business Media, New York).

## APPENDIX

The following pages show photos from the meeting:

- 1: Ireland's Cliffs of Moher, Dublin Castle, Sunday evening welcome reception with Irish music and dance, Monday morning opening session
- 2: Oral presentations and whole-audience discussions throughout the week
- 3: Tuesday's public lecture night, including Jim Miller engaging the audience in a hearing test ("Raise your hand if you can hear this tone."), Wednesday morning fun run along the Liffey River and city sights like the Samuel Beckett Bridge in the shape of a harp
- 4: Poster sessions
- 5: Coffee breaks within the industry display area, Friday's Coates awards, closing session
- 6: Walk to Trinity College, wine and canapés inside the Trinity College library, dinner in the Dining Hall, Deirdre Seaver performing Irish harp music, and the Coates family together with the conference organizers and children—missing Arthur Popper











