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Sustainable acoustics – survive, revive & enhance

P.J. Rogers*
Cole Jarman, 24B High Street, Addlestone, Surrey KT15 1TN, UK

J.R. Cowell †
Consultant to Arup Acoustics

1. INTRODUCTION

A key goal identified by the Bruntland Commission in 1987 in determining the three pillars of sustainability was to "*support and promote health and wellbeing*" (Target 24)[1,2]. Acoustics is central to these objectives. Our aural sense directly affects our safety, communication, social health and wellbeing[2]. Intelligent use of acoustics to control our aural environments and the materials we use have direct and in-direct effects on progress towards a sustainable future. Acousticians can therefore be responsible for a very positive contribution to sustainable living.

This paper explores specific actions that acousticians can take under the prioritised headings of Survival, Revival and Enhancement (see illustration in Figure 1). It proposes thoughts on practical action, stimulating a long overdue debate and highlighting areas for more research.

A. Context

We have seen growing threats to the world's ecosystems and substantial effects by, and now on, mankind[3-5]. These main threats are from pollution, overconsumption, and climate change. The shortages and security of our energy, food, water and raw materials and the growing instability of our ecosystems demand change[3,5]. The 'shortages' are driven by high levels of consumption, which in many parts of the world are unjust and extreme, and by global population growth which is now over 6.7 billion and growing exponentially towards over 9 billion by 2050[6]. In the words of the UK government "Past emissions mean that some changes are now inevitable whatever we do"…"It is therefore vital that we plan and prepare for these changes"[4]. The GEO4 report by the UN goes further by concluding that "the need couldn't be more urgent"..."to act now to safeguard our own survival and that of future generations"[7]. On urbanization, in 2007 for the first time more than half of people live in cities[7].

It is three years since the Stern Report was published. Have we heeded the advice to "take strong action now" [8]? There is plenty of historical evidence that the earth will adapt, given time, but the survival of the human species is much less of a certainty. Engineers must take responsibility and refocus efforts on a recovery plan, which matches our needs with the Earth's capacity. The UK Government proposes 5 elements to tackle climate change[4]:

i. Protecting the public from immediate risk (floods, erosion, water shortage, poor health)

* Email address. Peter.Rogers@colejarman.com
† Email address. Richard.Cowell@arup.com

ii. Preparing for the future (change house constructions, infrastructure and fundamentals of business)
iii. Securing a global deal in Copenhagen in December 2009 (replacement for the Kyoto Protocol, including a +2°C limit and 50% emissions reduction by 2050)
iv. Creating a low carbon UK economy (taking a lead, making fundamental changes)
v. Supporting people and businesses to do their bit (motivating change together)

The UK Engineering Council guides engineers (including many acousticians) towards 6 key actions[9,10] :

- Contribute to building a sustainable society, present and future
- Apply professional and responsible judgement and take a leadership role
- Do more than just comply with legislation and codes
- Use resources efficiently and effectively
- Seek multiple views to solve sustainability challenges
- Manage risk to minimise adverse impact to people or the environment

How can those of us who have training and experience of sound, and its control, best contribute to survival and restoration of our ecosystems?

We struggle to mitigate our way out of poor planning, policy, detrimental and antisocial human behaviour, weak regulation and designs that allow noise to be an acceptable consequence of development, until it becomes excessive. Clearest examples are road traffic and aircraft noise[11], which are problems of our own making. Dealing with noise pollution is of course important, but is essentially defensive and reactive. We should be striving to create safe and comfortable environments, but they should also be sustainable, using responsible materials and be socially inclusive[12]. "Good" acoustic design must therefore be sustainable acoustic design.

B. Sustainable Acoustics

The Bruntland definition of Sustainability[1] - *meeting the needs of the present without compromising the ability of future generations to meet their own,* applies fully to acoustics. We need to clarify our aural needs and protect these for future generations to define what is sustainable acoustics. One Planet Living (OPL) concepts[13-15]are now commonly used as foundations in the formation of policy and exemplar sustainability projects, such as the 2012 Olympics[14,16] . Although noise is only mentioned as part of the sustainable transport category, the expanded strategy for the Olympics embraces soundscaping as a necessary part of the health and wellbeing in the legacy phase[16]. Sound can contribute much more widely than this however, and this needs to be acknowledged. We explore the contribution of sound more thoroughly, under each of the OPL headings. At least eight of the ten sections are relevant to acoustics in the view of the authors, as listed: *Energy (Carbon), Materials, Waste, Transport, Heritage and Culture, Wildlife, Equity & Trade, Health & Wellbeing.*

Three headings can help focus our attention on the priorities for these contributions :

A. SURVIVAL : ability to meet our basic needs – mitigation & adaption
B. REVIVAL : restoring quality of life
C. ENHANCEMENT : how we might improve on our current quality of life & harmony

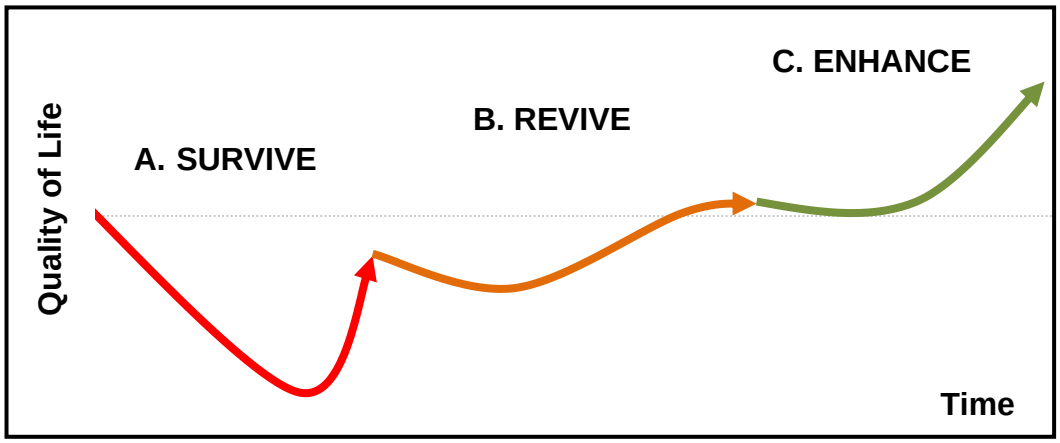

Figure 1: Priorities influencing Sustainable Acoustics

2. SURVIVAL

Charles Darwin once said *"It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change"*[17]. His concerns with the origin of species led to the articulation of evolution. Again, we must embrace the need for change as a species and permanently adjust our behaviour in order to survive and avoid further damage - potentially the sixth recorded extinction event in earth's history[6]. Acousticians are amongst the front line of designers. Solutions are being developed now that could ultimately make a real difference. Obtaining low carbon energy is critical, and will have implications for UK sustainable energy policy, potentially favouring micro-generation schemes as an 'effort on all fronts' solution. This is but one of a cocktail of significant challenges, which will include the need to expand renewable energy capability rapidly. Five categories from the OPL model are identified in more detail in table 1 below, as key areas for acoustic influence.

Table 1: Priorities influencing Sustainable Acoustics in survival phase

One Planet Principle	Acoustic Strategy	Contribution
Energy	• Reduce the mass of buildings (isolation and damping techniques) • Use of noise barriers as solar panel banks – renewable energy[11]	direct
Energy/ Materials/	• Specify use of materials that have proven environmental credentials (low embodied energy) over their lifecycle .	direct
Energy	• Make natural ventilation strategies viable in noisy environments	direct
Energy	• Remove planning/ regulatory obstacles to make renewable energy sources viable in the locality – noise pollution and wind turbines for example.	In-direct
Health & Wellbeing	• Protect living environments from noise pollution to allow basic ability to sleep, rest, relax, be able to function – more challenging in higher densities in existing urban soundscapes.	direct
Wildlife	• Reduce noise pollution in the oceans and on land where there is risk to our ecology and to species survival and proliferation.	direct
Transportation	• Reduce noise and air pollution - closely linked • Coach or Rail are the least polluting forms of transport currently in terms of emissions for a 200 mile journey[18] and a national noise action plan can be combined with the air quality strategy to encourage switching to public transport - reduce noise, use an integrated approach and inform fiscal measures	In-direct

Beyond the issues in Table 1, acousticians can consider new related areas for action:

A. Renewable Energy

We see accelerated technical advances to identify renewable energy sources and mitigate the associated noise issues e.g. near turbines. Acoustic design will need to be a central part of making this technology tolerable in the short term, and create opportunities to gather renewable energy for example as proposed by the London Mayor in 2003 to use noise barriers to double as solar power banks[11]. In contrast, the development and use of nanocarbon tubes in flat panel loudspeaker technology may lead to a viable carbon based alternative to scarce platinum as the catalyst in a hydrogen fuel cell[19]. Such a success would radically assist us on the path to a sustainable future.

B. Material Selection and waste reduction

Specification of sustainable materials for acoustic use is difficult[13,22]. This is mainly because there seem to be various ways to apply and present lifecycle and embodied energy information for effective assessment of eco-credentials[15,21]. The field of lifecycle analysis is quite advanced, with some databases available[15,22]. They tend to use different assessment ratings. Unfortunately there is little acoustic data to go with the emerging products, although this is likely to change with demand for it. Acousticians could partner and encourage manufacturers to do testing, or at least predict performance until test data is available. There are now some eco-alternatives, such as certified timber (FSC), biomass sound absorbers (i.e. reeds[23]), and recycled anti-vibration mounts. A more difficult option is sheep's wool, for which the full lifecycle is needed for direct comparison to be possible. For reduction of waste, work on recycled absorbers from almost any inert material is now well advanced. The use of cold extrusion techniques involves low embodied energy[24]. Probably the biggest difference that an acoustician could make is by reducing the embodied energy in a building, such as a shift to low mass of structures, whilst maintaining acoustic performance. Can we possibly go further, by using sound or vibration to optimise material performance? Vibrated concrete is one existing example but could acoustic energy reduce the energy used in more manufacturing or construction processes, e.g. resonant cutting, sonic lubrication ?

C. The needs of other species

Acoustic Ecology is a term defined by Schafer [2,25,26], which considers the *"delicate balance between organisms and their sonic environment"*. Many species rely on sound, much as we do, as an early warning system for: navigation, hunting, communication and mating rituals. Some rely more directly on sound and vibration than sight; such as bats, moles, snakes, dolphins, whales and orca. Noise is unhelpful because it interferes with this information and, in noisy areas, there is evidence of altered behaviour by birds (including fledglings), owls, frogs, fish and dolphins [27-30]. Research in these areas must be strengthened but this is no reason to delay action. Protection of conservation areas from noise pollution is called for by the World Health Organisation in their 1999 Guidelines for Community Noise [2 ‡]. We could go further by extending the efforts to protect wildlife corridors, for example.

‡ Table 1 of the guidance requires of outdoor parklands and conservation areas that "existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural low background sound should be kept low" to avoid disruption of tranquillity.

D. Monitoring

Sound technology already detects and monitors a myriad of changes in life - in human, animal and marine neonatal health, with ultrasound imaging, tracking of marine life such as whales, with hydrophones and use of sonar for sea bed profile imaging, depths and vessels. Expanding technology might improve monitoring of land based animals and bird populations, habitat behavioural data, polar ice movement and meteorological and, perhaps, climate assessments. A wider, more accurate, identification of resource quality (such as water exploration) might also help. Making historical records of our soundscapes to avoid their loss, could set valuable benchmarks for future revival plans. This process has started, with the BBC World service compiling a global audio record through their "Save our sounds" campaign[31].

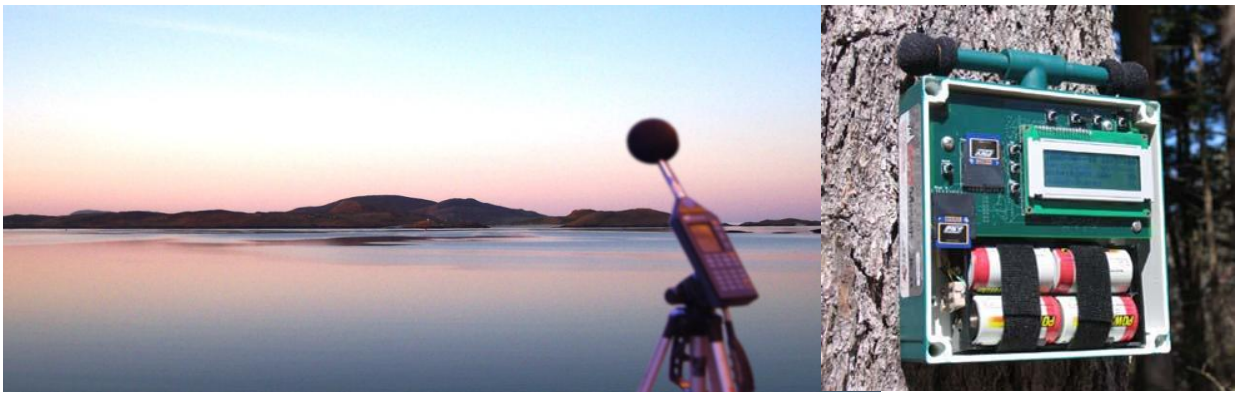

Figure 2: Recording and monitoring natural soundscapes (right: a "song meter" by Wildlife Acoustics[32])

E. New Technologies

We need to reduce unnecessary travel, until there is an sustainable alternative to a carbon fuel source. Video-conferencing and international mobile telephony have been with us for some time now. We can replace a lot of travel with wider, economically viable audio-visual communication networks. We are not yet at a point where good virtual spaces, and virtual acoustics are being created convincingly and made economically viable, but by prioritising affordable 3D environments we could provide a viable alternative and reduce the need for travel. Why not try to tackle local climate variation – e.g. inducing rainfall from passing rain clouds in drought regions; or perhaps create better conditions for carbon capture ?

F. Education

At a very basic level, acousticians and the institutes that support them can educate the new generation of acoustic practitioners. They can sponsor events and use audio material for education, communicating the sustainability agenda and necessary changes of behaviour.

G. Leadership

We can connect and unify people on a local, national and global scale by championing better listening[20] and communicating the voice of unheard future generations. An audio campaign through the media may be one way; a message into the Olympics, to reach a global audience, another? Here are further challenges for the institutes that support us. Acousticians should partner with other specialists and help politicians to recognise the value of good sound.

3. REVIVAL AND RESTORATION

We have lost many good quality soundscapes that surrounded people centuries ago[20,31] Consider the blind person in the busy city street, who relies heavily on their hearing for navigation and is likely to be far more disadvantaged. For revival, we must refocus our efforts on the priorities set out by Berglund in 2006[2], which centred on creating positive soundscapes and not just the noise control, that the World Health Organisation has focussed on. Table 2 sets out additional issues that require attention as part of the revival phase.

Table 2: Priorities influencing Sustainable Acoustics in revival phase

One Planet Principle	Acoustic Strategy	Contribution
Energy	• Making natural ventilation possible using openable windows by reducing man made noise in the environment, including noise control as integral part of new infrastructure.	direct
Transportation	• Reduce noise pollution at source or through new infrastructure.	direct
Culture & Heritage/ Trade & Equity	• Protect heritage sites from noise pollution (e.g. Stonehenge) • Use sound to enhance cultural identity (local sound marks like Big Ben[33]). Restoring the connection of people to their surroundings and introducing aesthetic and drama to emphasise with sound. • Provide a draw to sustainable communities – gathering places. • Balance the need of community against the need for audible night time entertainment detrimental to the soundscape[34].	direct
Wildlife/ Health & Wellbeing	• Protect designated areas from noise pollution and creating optimum conditions for species to thrive • Include wildlife and therefore their sound back into our living environments to improve the connection to nature. [35-37]	direct
Health & Wellbeing/ Trade & Equity	• Use sound to revive poor aural environments to restore health, wellbeing, social inclusion within all of our living environments. • Improving desirability of living conditions - affecting property value	direct

A. Conflicts

Conflicts of particular note include: high density living with transportation noise; natural ventilation with external noise and human with the needs of wildlife. Acousticians often provide the opportunity to enable alignment rather than conflict through the solutions they can offer.

B. Indoor Environments – protection v connection

Using natural ventilation to provide a connection with outside provides an opportunity to filter external sound through design. Aural isolation is highly stressful (e.g. isolation cells). Maintaining a connection to the wider natural environment is an important factor that reinforces the visual cues and the connection necessary for our wellbeing[36,37]. Just making living environments quiet is not sufficient on its own[38]. With careful design that provides flexibility for the level of protection versus connection and improved quality, we can restore wellbeing for people living within high density, “sustainable”, buildings. Positive sound may be a useful tool in the design of our homes for wellbeing, reduction of social tensions, improved social inclusivity and cohesion[12].

A better understanding is needed of the balance between isolating people from their communities and allowing the creation of a vibrant community without annoying neighbours.

The Licensing Act 2003 promotes the prevention of public nuisance. Perhaps, instead, we should call for support for creating and protecting public amenity. This might then address the paradox of protection versus the expectations of people with a genuine focus on community[34]. Good speech intelligibility is also needed for a fully inclusive environment to be created and needs to be maintained where hard surfaces exposing thermal mass are used in designs.

C. Transportation

Most transportation is becoming quieter, including aircraft, vehicles, road surfaces and tyres. This is a slow process and has been offset by the increase in traffic. In time, we need alternative non polluting ways to travel. The opportunity is there to design new systems to be considerably quieter or reduce the impacts through an integrated strategy on transportation, as suggested in table 2. This will be the single most effective way to reduce noise pollution.

D. Soundscapes

There is an interesting parallel between reduction in the biodiversity and our loss of aural experience, amenity and information. We can revive better aural soundscapes, provided that we know what we had. Work to catalogue them would help[31]. Dialogue for quantifying noise pollution on a large scale has started with the intervention of the European Noise Directive[39] and efforts to map noise in major agglomerations and identify 'quiet areas' within them. Local authorities can then create action plans to improve and protect them on a local level. This is promising for the revival phase, but needs to focus more clearly on positive soundscapes. Cox and Mags propose a way forward in the classification of soundscapes, in an area that is coming of age and now looks likely to shape the urban sustainable designs of the future [33].

In Acoustic Ecology, soundscapes contain either "soundmarks" or "keynote" sounds to articulate them[25,26,40]. Positive elements also distinguish, and enhance, our local sense of place.[41] We should expect interesting challenges e.g. risk from vehicles approaching more quietly and the need for audible warnings, tackling wildlife noise nuisance and management.

Our connection with nature though sound is as important as our visual connection. Flowing water, insects or birds produce positive sound in the right context[36]. Equally, we can appreciate man made sound, the sound of sport being played, children playing and 'soundmarks' that enhance our sense of place[33]. The Mayor of London's Ambient Noise Strategy challenges acousticians to consider the quality of our urban soundscapes[11]. This approach can be extended to sustainable developments as part of national and international benchmarks for Planning, Licensing and Environmental Protection frameworks.

E. Wellbeing of Wildlife

Noise is a stressor for wildlife[28]. We often only see the impacts as numbers decline, and perhaps we need to be more focused on the onset of stress in wildlife rather than simply their survival. Increased awareness and the actions listed in Table 2 provide the best chance of realising the wealth that nature offers us.

F. Regulation

Regulation and law making are slow, but needed. Currently sound does not feature strongly in guidance on sustainability, and this needs to change. A revision of PPG24 is long overdue[34], with its replacement still under consideration. The UK Institute of Acoustics has called for reconsideration of the UK Government intention to separate micro wind generation

from the planning process[42]. Noise pollution must not be tackled as a second thought. The Environmental Noise Directive[39] and resulting local Noise Action Plans may help but quality aural environments are not just a local issue, but a central human need that affects our health and wellbeing[2]. Regulation is needed for the difficult times ahead to maintain a clear strategy.

G. Research

We must strengthen the evidence base for the potential positive health benefits of reducing noise and creating helpful sound. We also need better measurement and clear understanding by what we mean by tranquillity and the influence of positive sound.[33,35,36,40] Variations across cultures and society should be researched in more depth[40]. We need quality targets for soundscapes and the thresholds for acceptance in urban settings particularly. Research into sustainable materials and acoustic qualities and new sound technologies must be funded well.

4. ENHANCE – IMPROVING HEALTH AND WELLBEING

After survival and revival, we can then concentrate on enhancing our environments to improve the health and wellbeing of humans and other species. We can support the social aspects of sustainability, often a neglected area[20]. Noise should be treated more seriously as a pollutant which is fiercely discouraged and regulated. Incentives are then needed to encourage the use of positive sound in new and existing environments to enhance them, taking an inclusive and integrated approach to community. This contributes positively to better social behaviour, the ability to enjoy culture, leisure, work, nightlife, or privacy and relaxation both inside and outside our living spaces. Acoustic designers need to work with urban designers to create local aural identities, with flexibility to cater for the changing needs of their community; connecting people with their community and surroundings positively.

A. Natural Wealth

Nature provides us with considerable wealth, which is a new commodity and capital that we must consider against our focus on consumption. The plight and value of the honey bee is an example which signals serious consequences for our food supply, but the loss of bees also means loss of one of our cherished summer sounds. Enhancement of our aural environment therefore needs to be aligned with conservation, and the formation of a clearer understanding of the value that nature brings to us. For the future, we can learn from sound in nature to enhance our designs.

B. More positive sound

The evidence base for using the positive aspects of sound to improve health, wellbeing, and comfort looks promising[2,43] but needs strengthening. Sound therapy, or cymatics (from Greek, meaning ‘wave’) is practiced on the fringes of alternative therapies, but has the potential to become mainstream, where an evidence base can be established[44]. Certainly chanting mantras use sound in religion to connect us to raise or uplift our spirit. Could learning from these areas eventually influence the way we design living environments in order to maximise how we use sound to enhance health? Sound certainly provides pleasure and enjoyment through music, and enhances cultural connection to nature. Sound is therefore a part of our identity and who we are as a species, and our relationship with the world around us. We cannot “switch off” our hearing, so acousticians have an important job to do to help create and sustain suitable environments that meet our needs; whether sleeping, working, playing or connecting with the ecosystems around us. The scope of acoustics is wide, crossing many boundaries including: science, engineering, medicine and the arts. Acousticians therefore

need to also remain open to integrating our expanding knowledge about sound into our approaches.

5. CONCLUSIONS

We need change to create a sustainable future. We are also clear of the need and ability for acoustics to contribute to the success of sustainable design and a sustainable future, beyond dealing with climate change. A change is however needed from the existing defensive stance towards the creation of "*soundscapes that are supportive to health*"[2], which *prevent, support and promote health and wellbeing* (cf Target 24)[2].

This paper has set out specific suggestions for action and further research, against the priorities to aid our survival, revival, and then enhancement of our quality of life through sound. The One Planet Living model enables us to quantify and set out an action plan. The framework indicates that eight out of ten of the categories have connections that require contributions from acoustics. The authors see yet more areas for contribution beyond that. These have been listed and specific suggestions made for realistic contributions that acousticians can offer. It is clear that sound could play a far greater role in our survival, and restoration of our ecosystems and living environments than we might initially think.

Commitment to changing our ways is therefore a pre-requisite for progress, which is perhaps the challenge more widely. Perhaps the greatest danger to success is the risk that acousticians may underestimate the potential impact of acoustics on sustainability. This paper has set out a map for making advances and calls for action, debate and learning to sustain and unlock the full potential that sound and our aural sense provides in creating a truly sustainable future that includes mankind. "Good" acoustic design must therefore be sustainable acoustic design.

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