

## Recommendation of best practice

Main concern about operating large airgun arrays in terms of inflicting damage is thus to make sure that the array is not fired at full power when animals are within, directly below or otherwise very close to the array. Particular concern surrounds start up of the array. Less concern should be given to animals approached by the survey ship while in full operation and animals who themselves actively approach the array. In those cases, the animals have the possibility to flee well in advance of levels becoming potentially dangerous, whereas an animal diving below the array at start up may be caught in a difficult situation.

Best practice to prevent damage to marine mammals during seismic surveys would be aimed at preventing animals from being exposed to dangerously high sound pressures. Although there is little experimental evidence on the efficiency of ramp up procedures, these are still considered a key component of best practice.

- The airgun array should not be larger than needed for the specific survey
- The array should not be started at full power, but individual airguns should be added one by one or if not possible, output of each airgun slowly increased by manipulation of pressure.
- The ramp up procedure should occur over a period of about 20 min and can occur while the survey ship is *en route* to the starting point of the transect line.
- Ramp up should not be initiated if marine mammals are inside the array or within 200 m of the array.
- If proper ramp up cannot be performed for technical or other reasons, other measures should be taken to assure that no animals are within 200 m of the array at start up.
- If the array is shut down for any reason while on the transect line it can be re-initiated at full power given that the silent break is not longer than 5 min. Otherwise a full ramp up procedure should be followed.
- The array should be shut down completely between lines, if the transit time is longer than the time it takes to conduct a ramp up and a full ramp up should be initiated prior to arrival at the next line. If transit time is less than 20 min the array can be operated during transit, preferably at reduced power output.
- Observation of marine mammals inside or in the vicinity of the array during surveys at full output power should not in itself lead to shutdown, but animals should be observed and shutdown performed if the animals show obvious signs of

discomfort. A log of such observations should be kept on the ship and reported as part of the cruise report.

- Airguns should not be used outside the transect lines, except in the cases mentioned above (ramp up prior to arrival and on short transit lines) and for strictly necessary testing purposes. Testing the array at full power should be initiated with a ramp up procedure as above.

#### *Explosive sound sources*

The above discussion of the fictitious nature of the source level in relation to actual sound pressures near an airgun array does not apply to explosive sources, exactly because these are point sources. In this case sound pressures close to the explosion can reach very high and potentially lethal levels. Thus, an assessment of possible effects of explosive seismic sound sources is strongly recommended, when single detonations exceed 1 kg TNT or equivalent (in terms of peak pressure generated). One kg of TNT detonated at depth creates a peak pressure of 276 dB re 1  $\mu$ Pa at 1 m (Urlick 1983). The pressure wave is attenuated to about 230 dB re. 1  $\mu$ Pa (the safety level suggested by Southall et al. 2007) at a distance of roughly 200 m, which thus constitutes the margin of the safety zone. A safety zone with a radius of 200 m is manageable in terms of assuring that no marine mammals are within the zone at time of detonation, but with increasing size of detonations and hence larger safety zones, it becomes increasingly difficult to monitor the entire zone and additional measures to prevent damage to marine mammals may be required.

An assessment of an explosive detonation should include estimation of safety zone, based to the best ability on actual/expected sound transmission properties of the surrounding waters, keeping in mind that transmission loss in arctic waters can sometimes deviate substantially from simple predictions based on geometrical spreading.

Good practice in relation to explosive detonations includes

- Detonations should not occur at night or under poor visibility conditions, where the margins of the safety zone cannot be monitored visually.
- Detonations should never be initiated when marine mammals are known to be present inside the safety zone.
- The main detonation should be preceded by one or more small detonations of increasing magnitude intended to deter any undetected marine mammals out of the area. Sufficient time should be allowed between pre-detonations and main detonation to allow any marine mammals to leave the safety zone, yet not so long time, that new animals may enter the area.

- Several large detonations can be made in a series without pre-detonations in between if they occur with a reasonably small interval to prevent animals to re-enter the area between detonations.