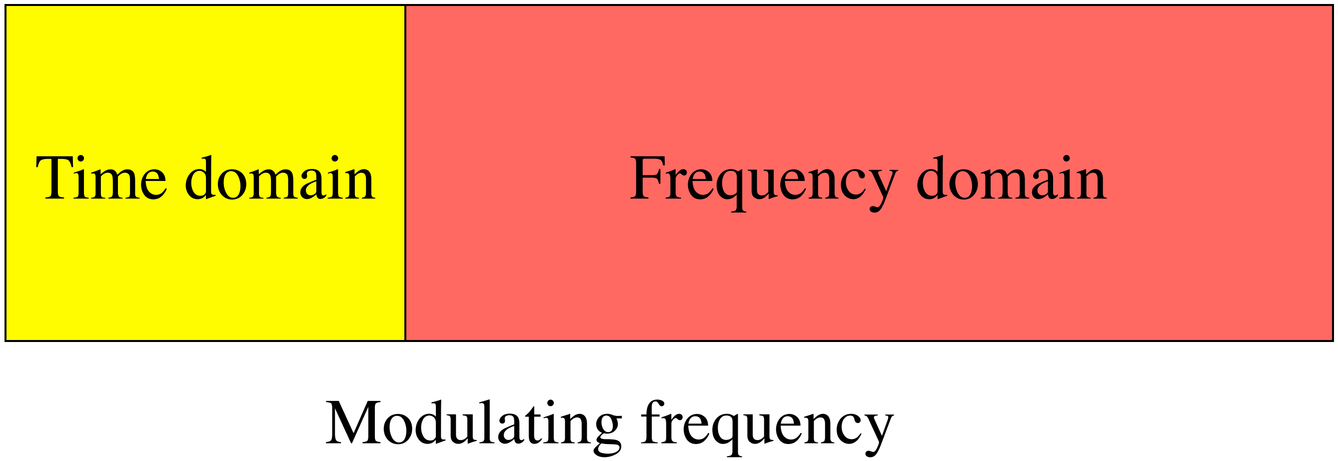
Sound Transmission

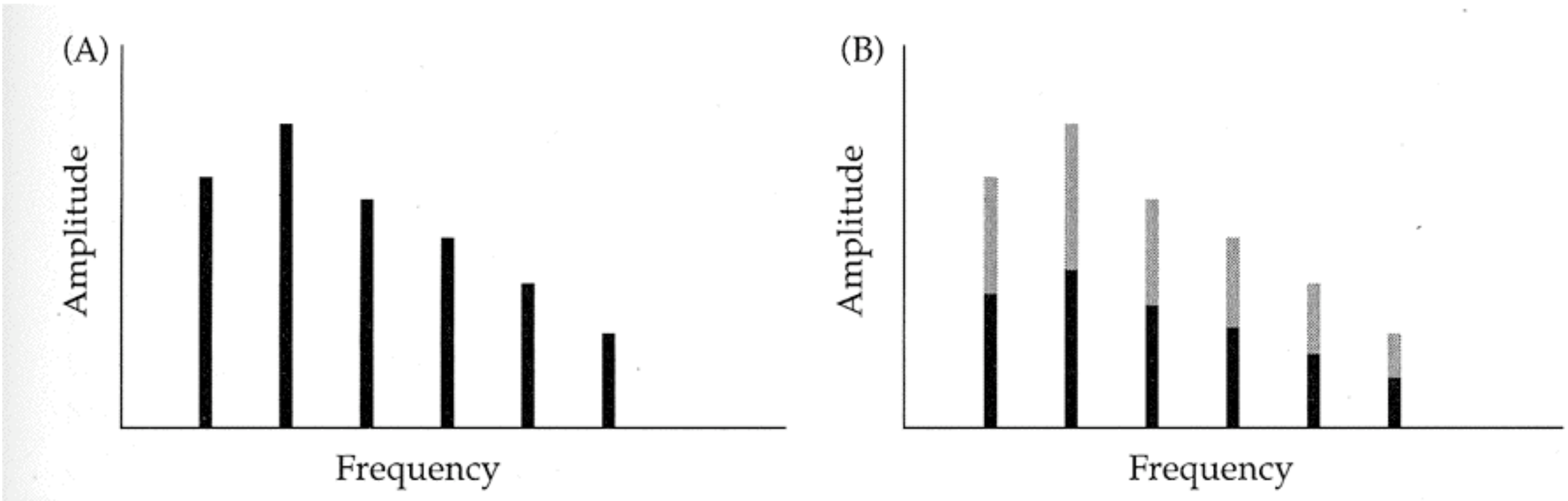
- Signal degradation in frequency and time domains
  - Attenuation, absorption and scattering
  - Boundary effects and density gradients
  - Noise
- Signal optimization
  - Ranging

Time-frequency perception



- All animals have a threshold frequency at which sounds are perceived either in the time or frequency domain
  - Determined by auditory system, species specific
- In each domain, transmission distortion can result from attenuation, loss of pattern and masking by noise

Global attenuation



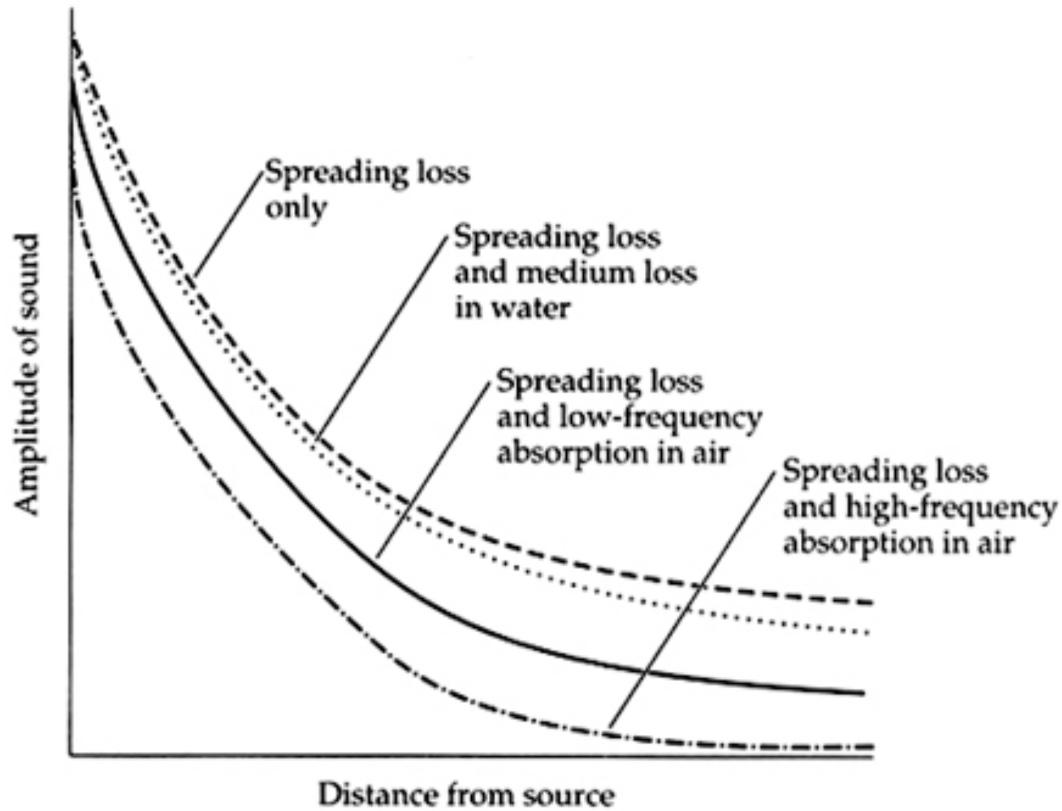
- Spherical spreading loss: $P_d \leq P_0 / d^2$
- Recall: - 6 dB for every doubling of distance
- Spherical spreading is frequency independent
- Greater in near field

Absorption depends on medium

Absorption values:

water = 0.008 dB / 100 m
air = 1.2 dB / 100 m
ground = 6 dB / cm

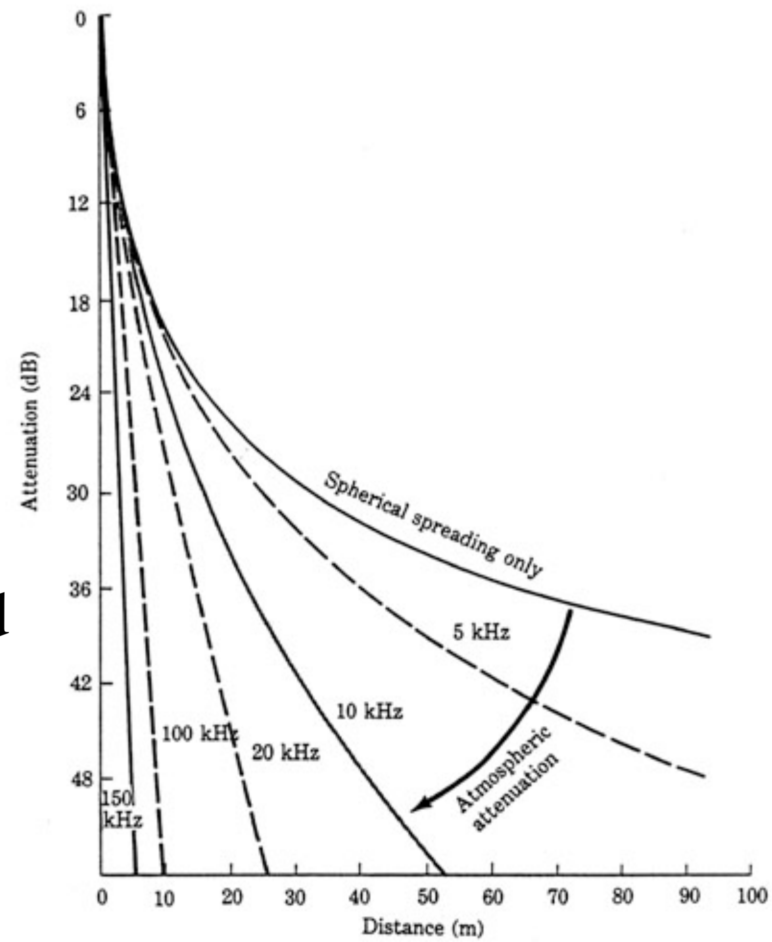
Increasing absorption results in decrease in amplitude



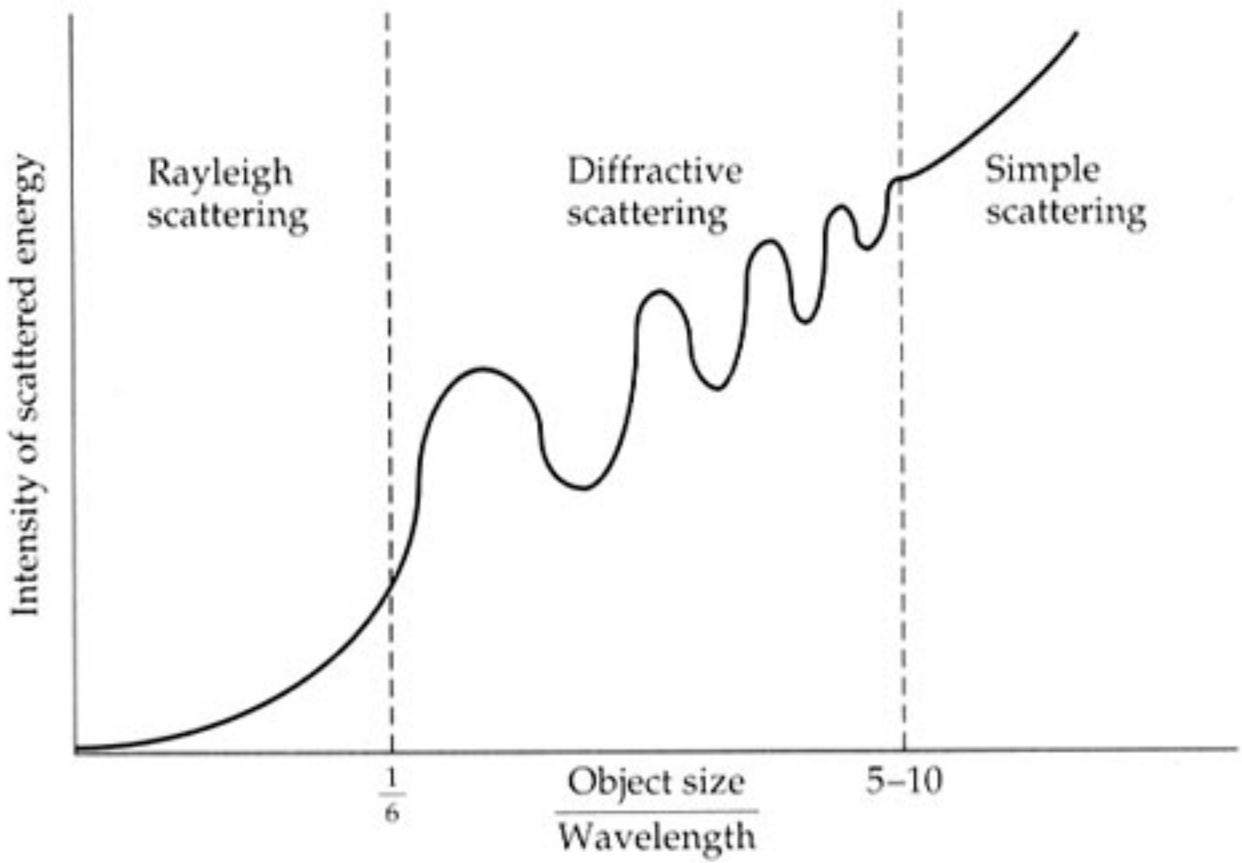
Absorption depends on frequency

What will happen to a broad bandwidth signal as it moves away from a source?

What media will be affected the most? Air or water?



Scattering leads to frequency filtering



Frequency transmission problem

- Varied thrushes produce tonal songs in mature oak forests. If the diameter of the trees is 0.5 m, which frequency will exhibit the least attenuation?
- 340 Hz or 3.4 kHz or 34 kHz
- Wavelengths = 1 m; 0.1 m; 0.01 m

- Answer: 340 Hz

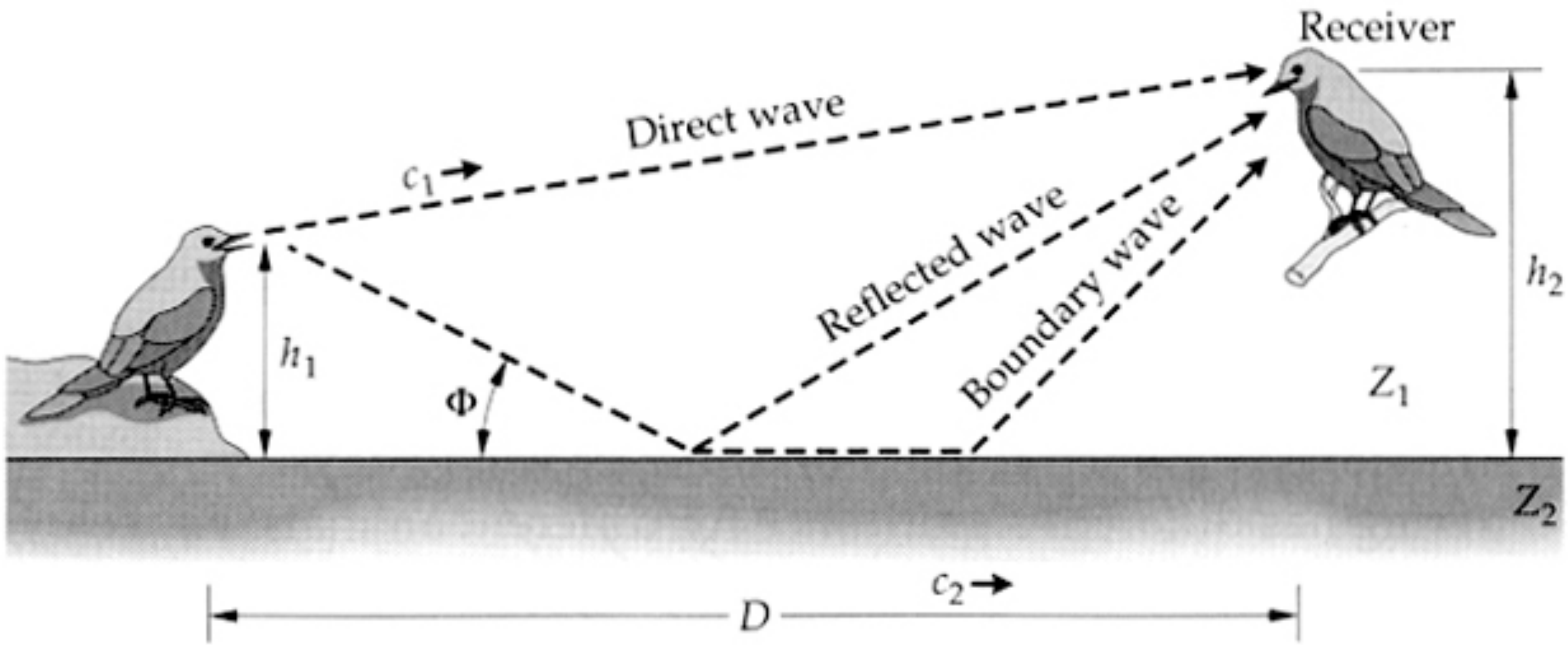
Scattering and absorption in different environments

For 1 to 10 kHz:

- Broadleaf forests: 2-35 dB /100 m
- Coniferous forests: 2-20 dB / 100 m
- Open areas: 2-200 dB / 100 m

- Water: much lower than in air Why?

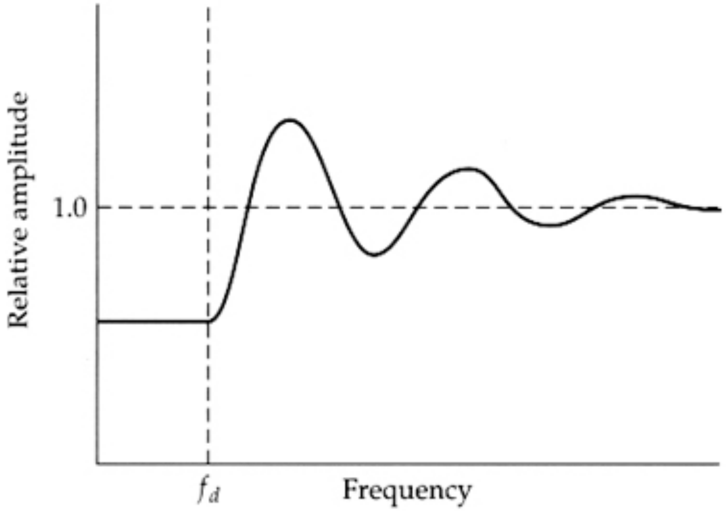
Signal propagation near boundaries



- Boundary waves occur if the signal is absorbed and reradiated by the second medium or a surface wave propagates.
- Only occur when impedance of medium 2 > impedance of medium 1, i.e. no boundary wave at water-air interface for water-borne sounds.
- Recall that reflected waves can interfere with direct waves due to phase shifts

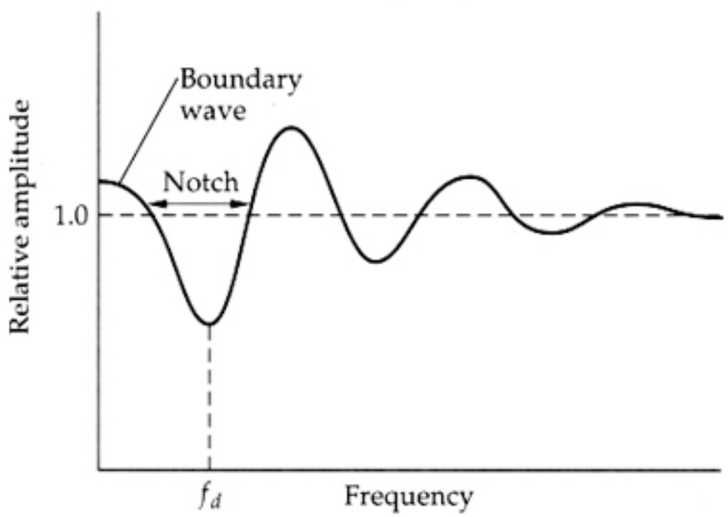
Transfer functions

indicate how frequencies are amplified or suppressed



Reflected waves cancel direct waves when the reflection is out of phase

Figure B Transfer function of sound propagating in water just below the surface.



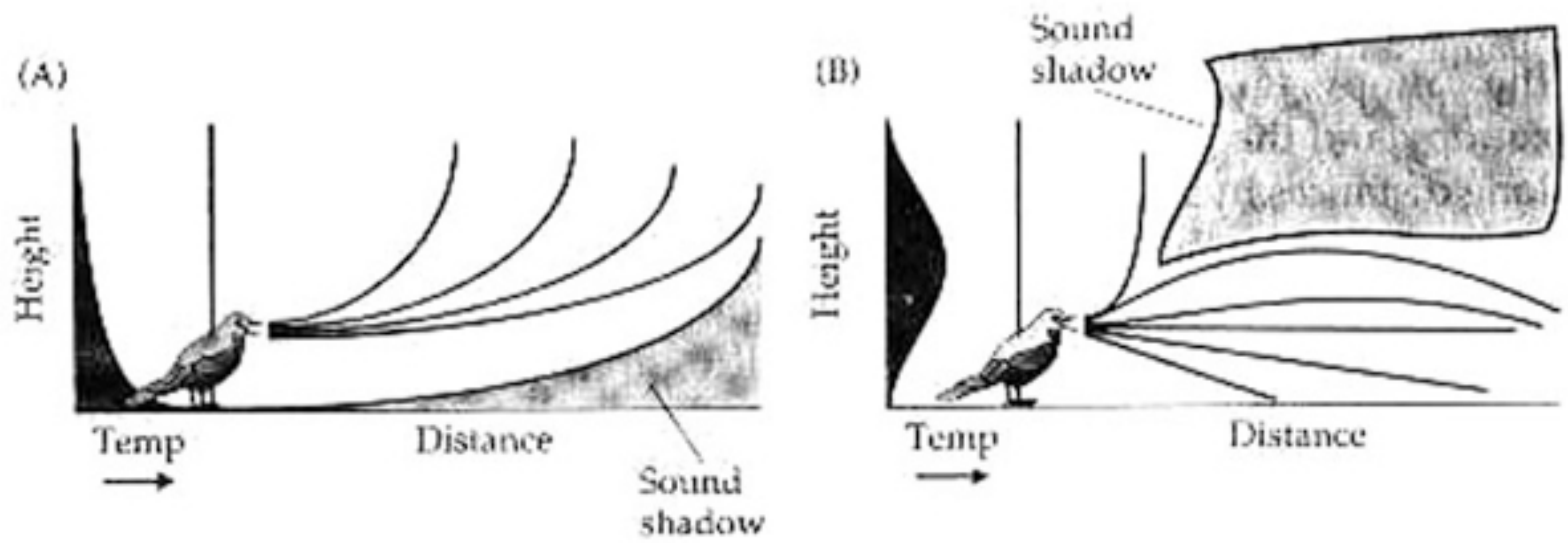
f_d = the minimum frequency where direct and reflected waves cancel at receiver

Figure C Transfer function of sound propagating in air close to porous ground.

Notch ranges from 300-800 Hz. Few ground animals use it.

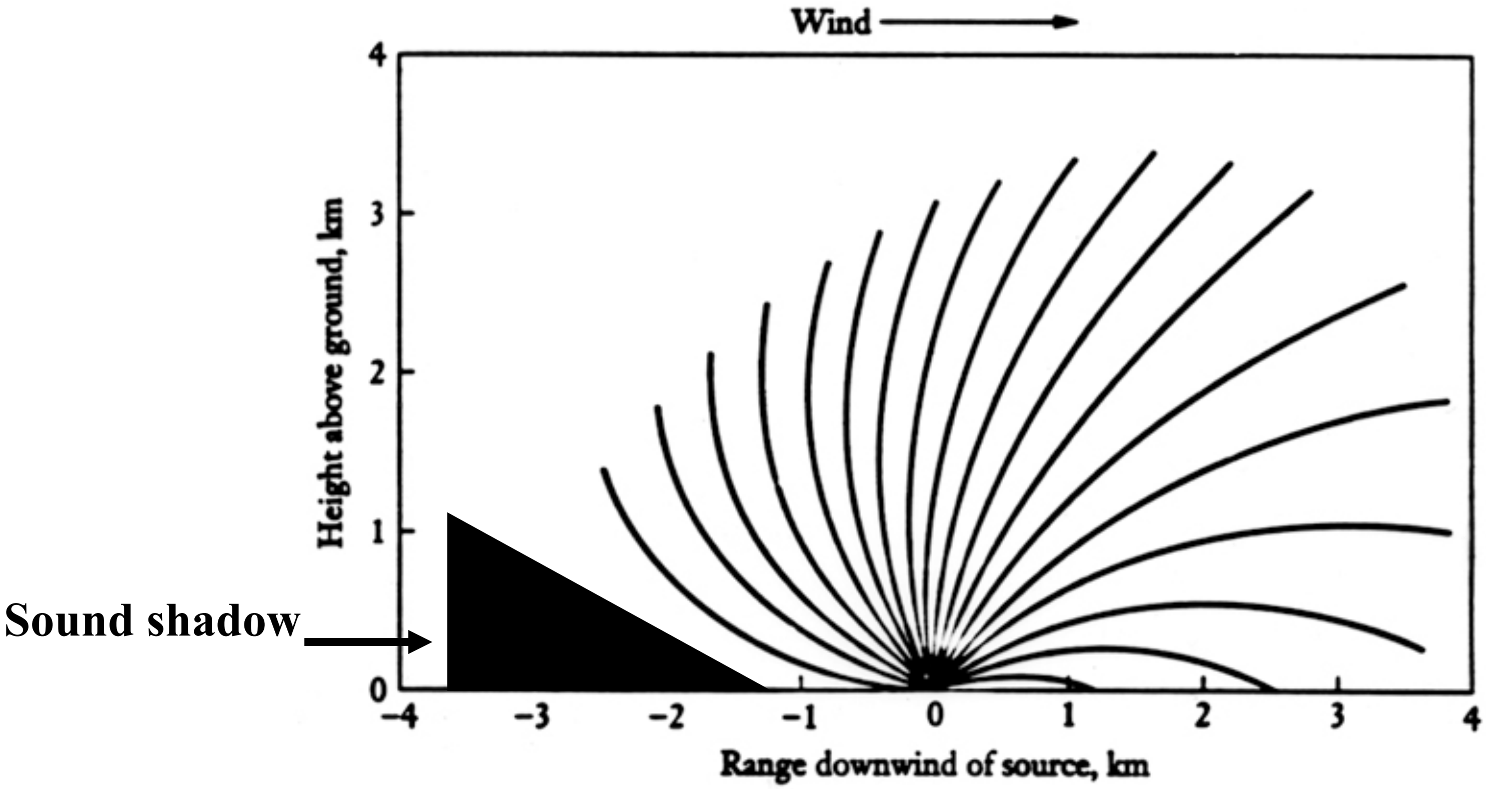
Temperature gradients cause refraction

- Sound velocity increases with temperature and pressure
- Sound refracts into less dense or cooler medium
- High to low temperature gradients bend sound back toward low temperatures and v.v.



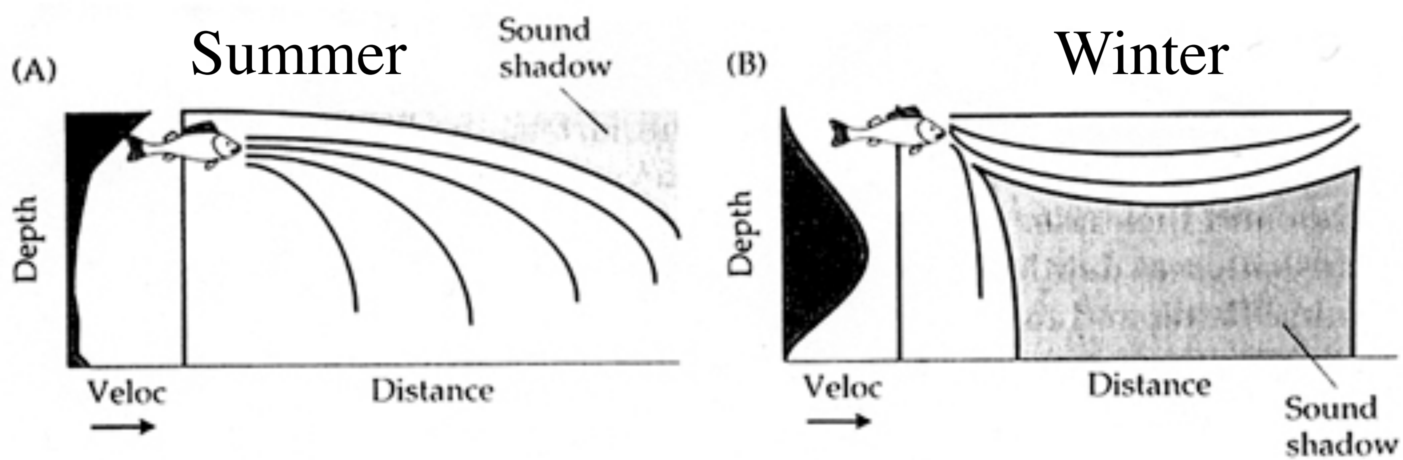
Desert Forest

Wind can refract sound

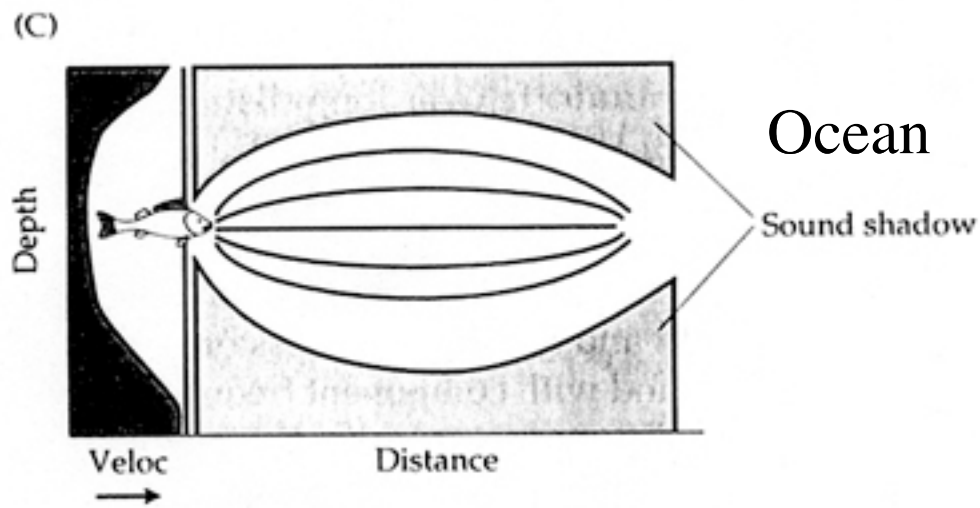


- •Wind speed increases with distance above ground
- •Winds can alter sound velocities by 5-10%
- •When sound moves against the wind, it is refracted away
- •Creates a sound shadow upwind

Density gradients in water cause refraction



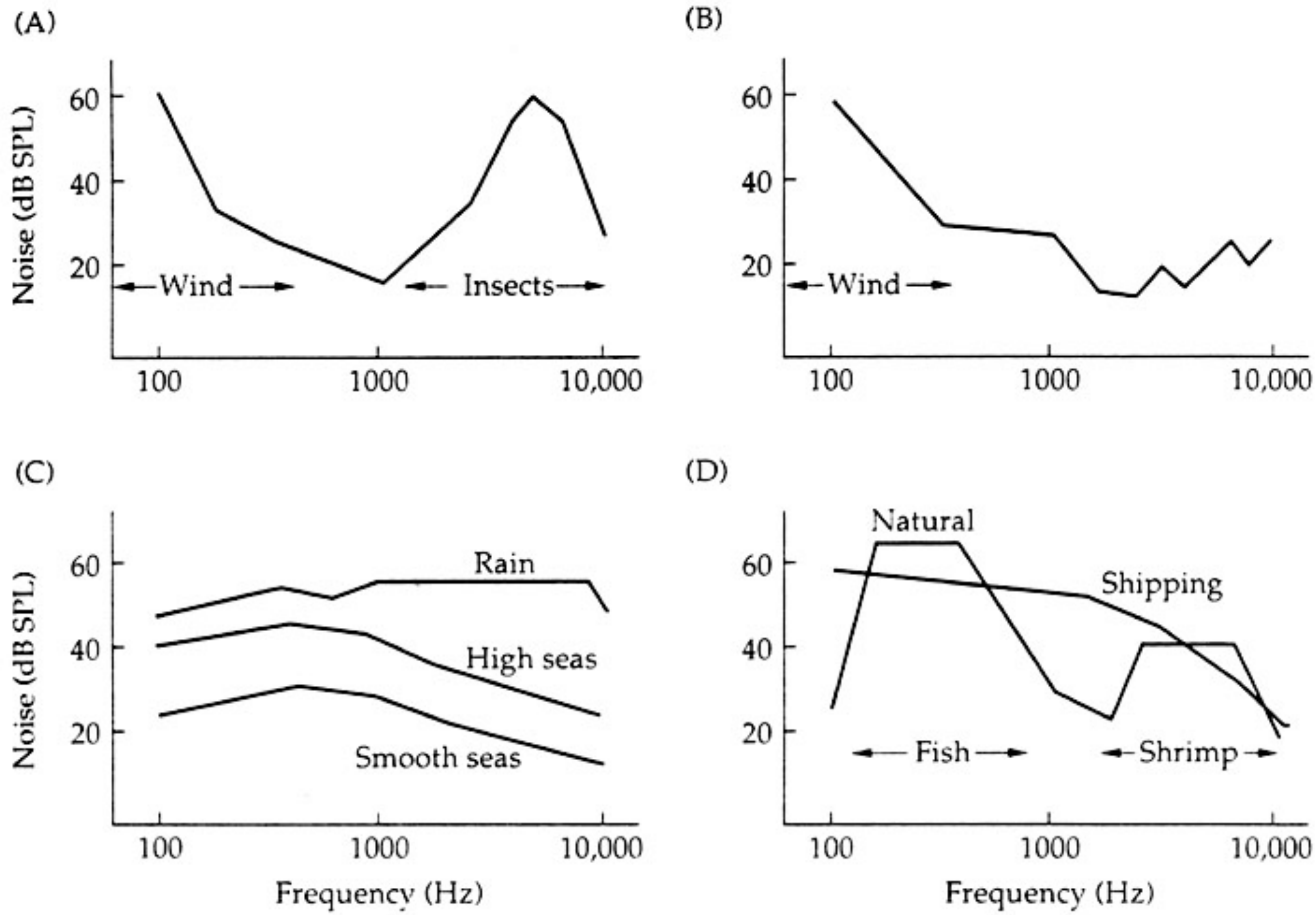
- Density gradients caused by changes in temperature, pressure, or salinity
- Sound shadows at surface in temperate summer
- Sound shadow in deeper water in winter
- SOFAR channel at 1.2 km depth in ocean



Background noise can mask sounds and change spectral pattern

Forest

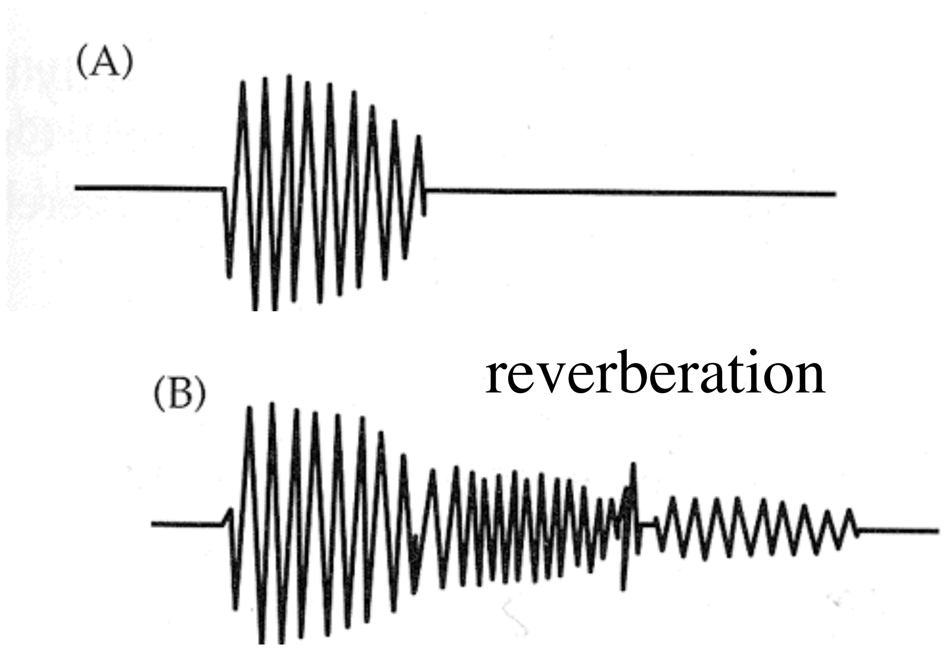
Pasture



Open ocean

Coastal ocean

Distortion in the time domain



Reverberation causes loss of temporal patterning

Vegetation causes scattering

Fig. 9. Amplitude fluctuations of a 2-kHz tone recorded 60 m from a speaker in a deciduous forest. Total duration, 1 sec. (After Richards and Wiley, 1980.)

Low AM rates (below 10 Hz) resist reverberation in forests

Wind can add low frequency AM in open grasslands

Distortion of AM vs FM by scattering

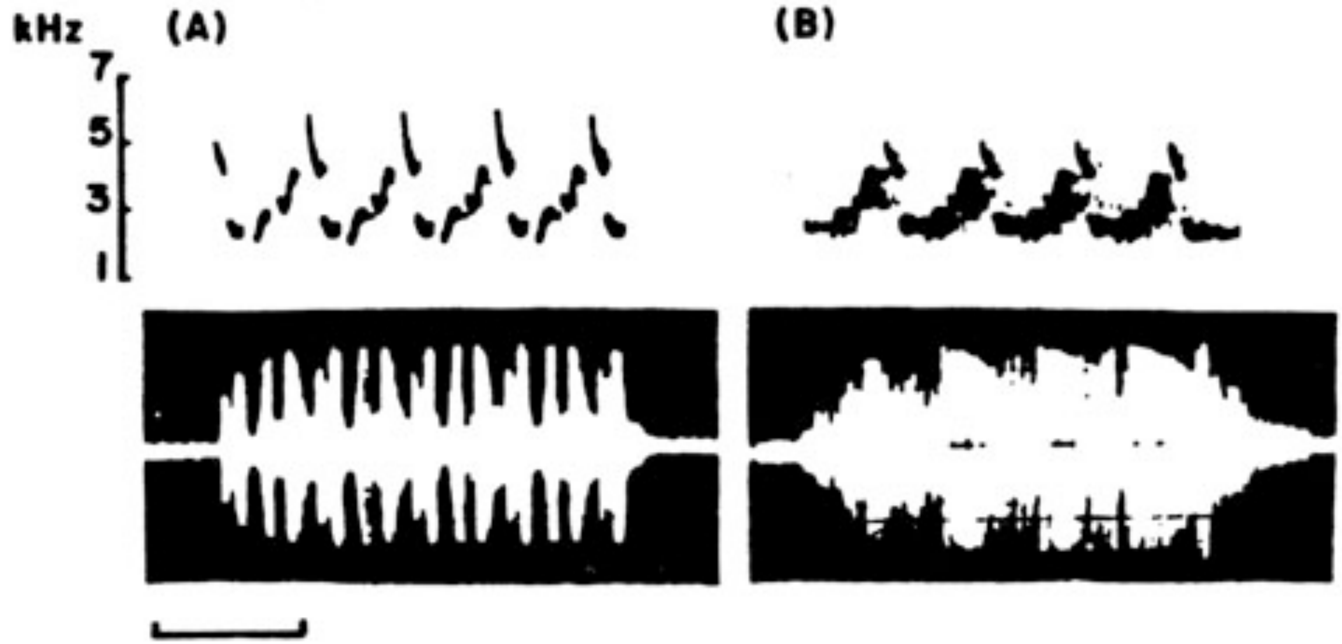
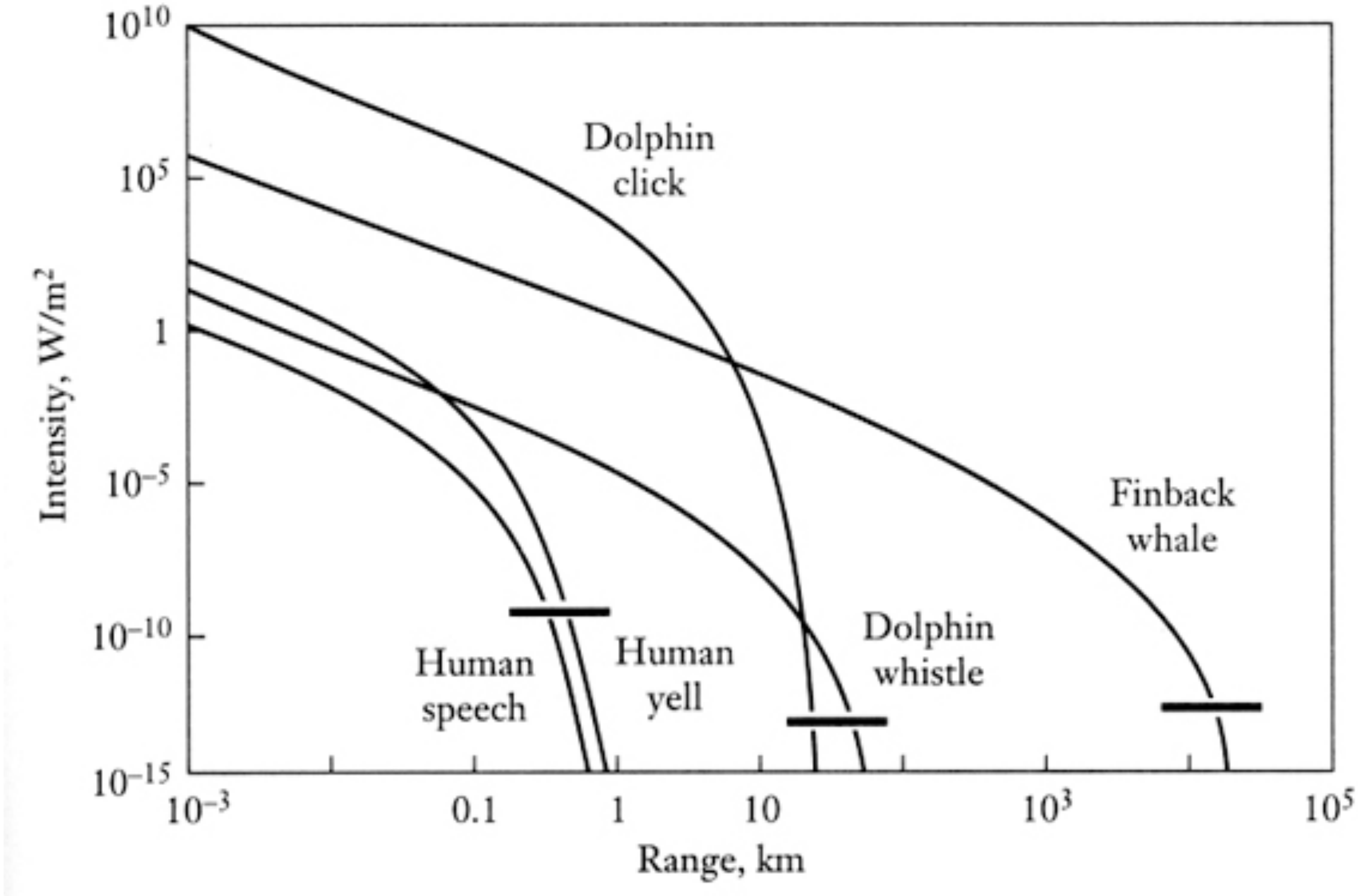


Fig. 7. Songs of Carolina Wrens (*Thryothorus ludovicianus*) recorded 10 m (A) and 50 m (B) from the singing bird to show the effects of reverberation. Upper, sonagram; lower, oscillogram. Time mark, 1.0 sec. Note that the basic pattern of frequency is preserved at a distance of 50 m although the pattern of amplitude is completely lost.

Signal design is important for long range communication



Signal design parameters

- Bandwidth
- Frequency
- Duration
- Modulation type and rate
- Location of sender and receiver
- Transmission medium

Some principles of acoustic signal design

- Sound travels further in water than air or ground
- Lower frequencies travel farther
- Tonal signals travel farther because more energy is concentrated in one bandwidth
- Terrestrial animals near the ground avoid the notch
- Aquatic animals can make use of sound channels
- Animals use frequencies that avoid ambient noise
- Slow modulation better in forests
- Fast modulation better in open areas
- Less scattering in water predicts use of higher frequencies

Optimal Signal Design

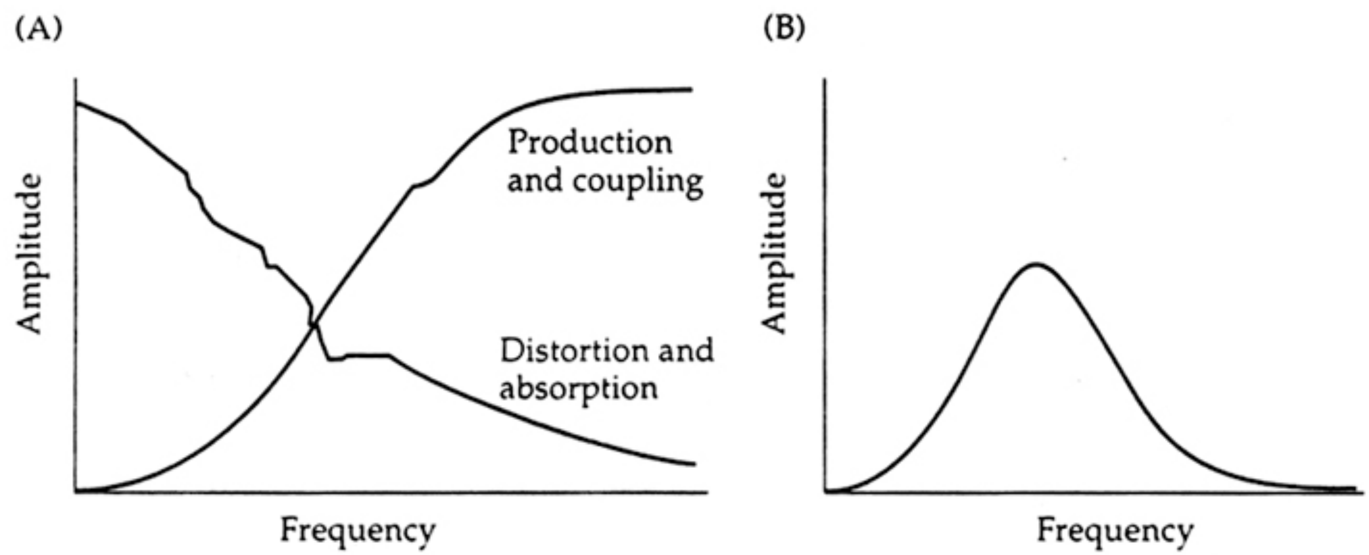
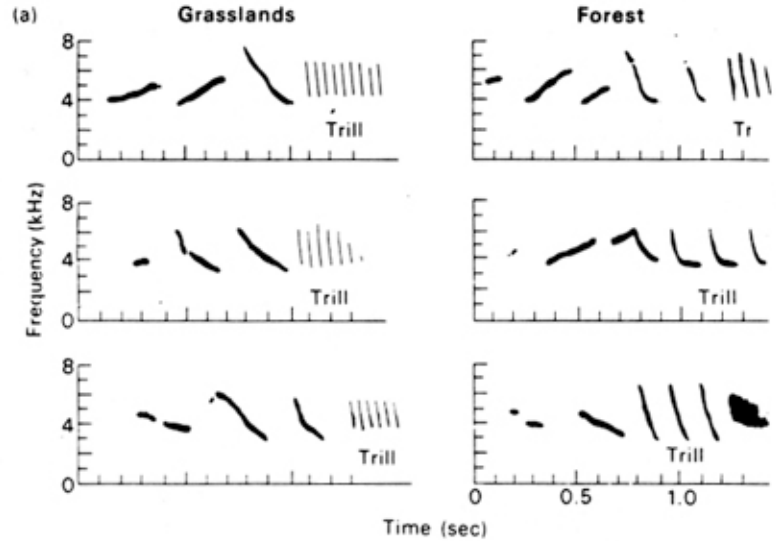
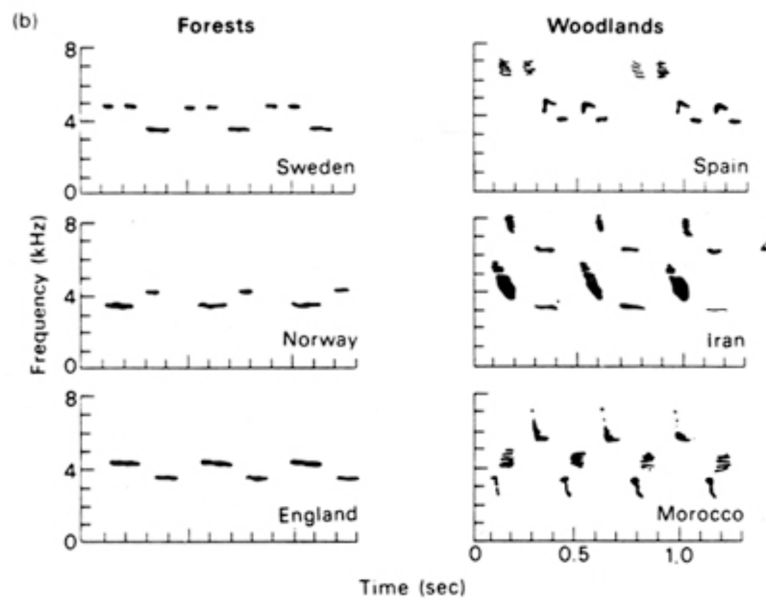


Figure 5.9 Maximization of sound signal propagation. (A) Typical curves showing frequency dependence of sound intensity given production processes versus distortion and absorption processes. (B) Composite effects of the production and distortion curves relating sound intensity to frequency. The peak in the graph occurs at the optimal frequency for communication.

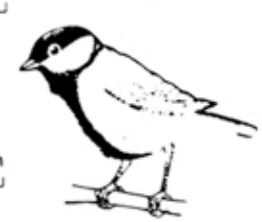
Adaptive signal design?



Chingolo sparrow
Argentina



Great tit



Transmission distance can vary by call

Why?

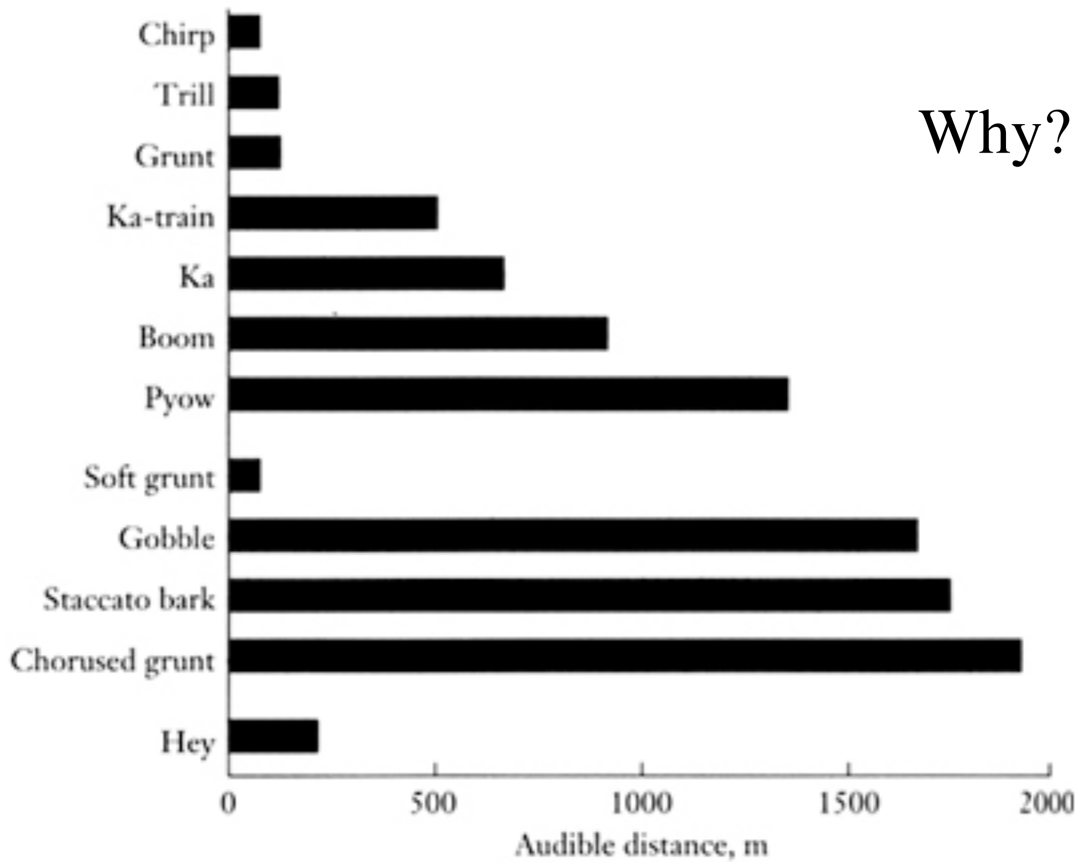


Figure 9-18 The measured range of primate calls in natural environments. (From Brown 1989, 228.)

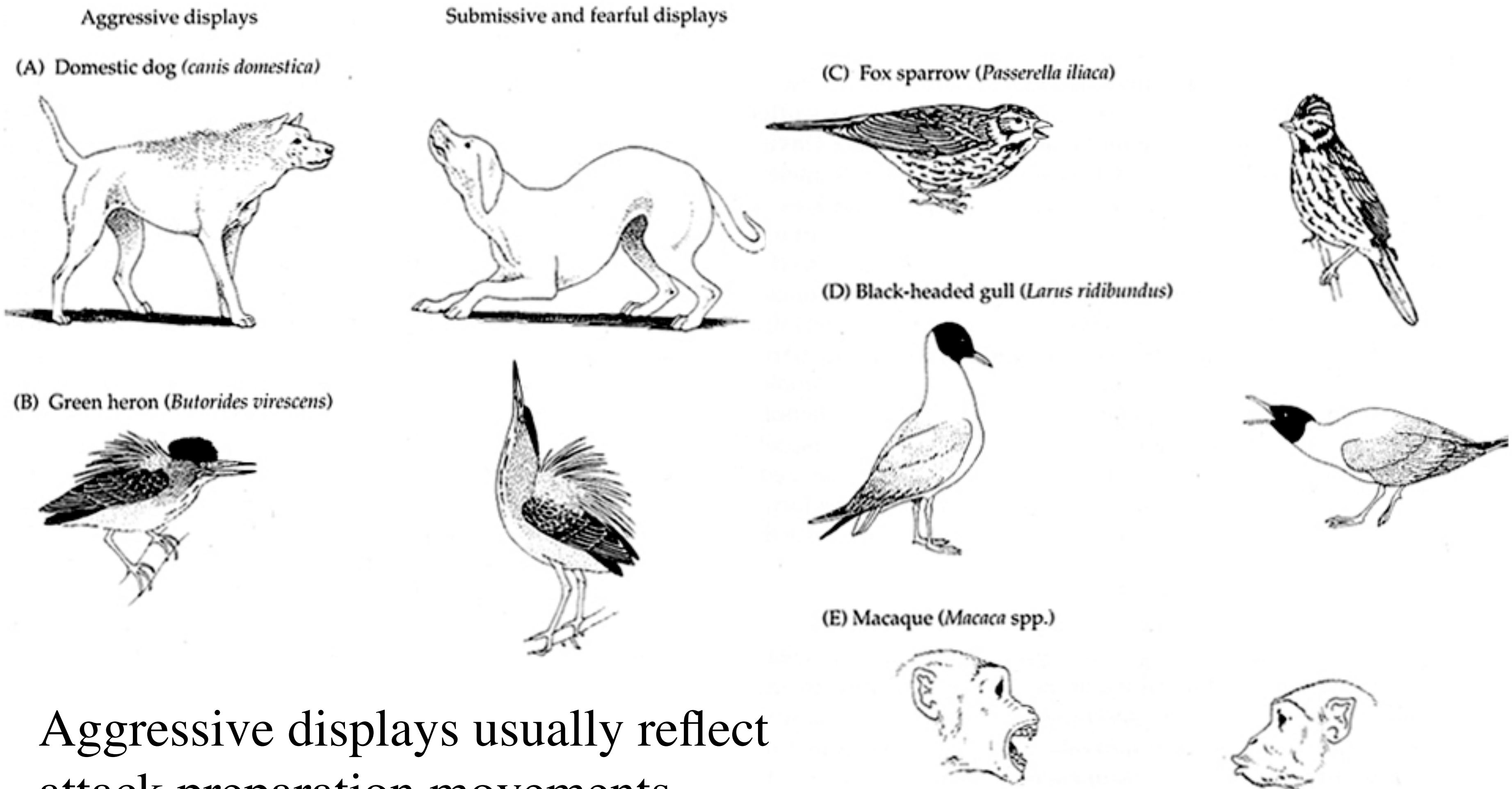
Range of detection

- Some signals provide information on distance to caller
- Detection range depends on amplitude at source, frequency, and type of modulation
- If range information is needed, signals should incorporate features that degrade predictably with distance
  - wide bandwidth
  - temporal patterning

Territorial Signals

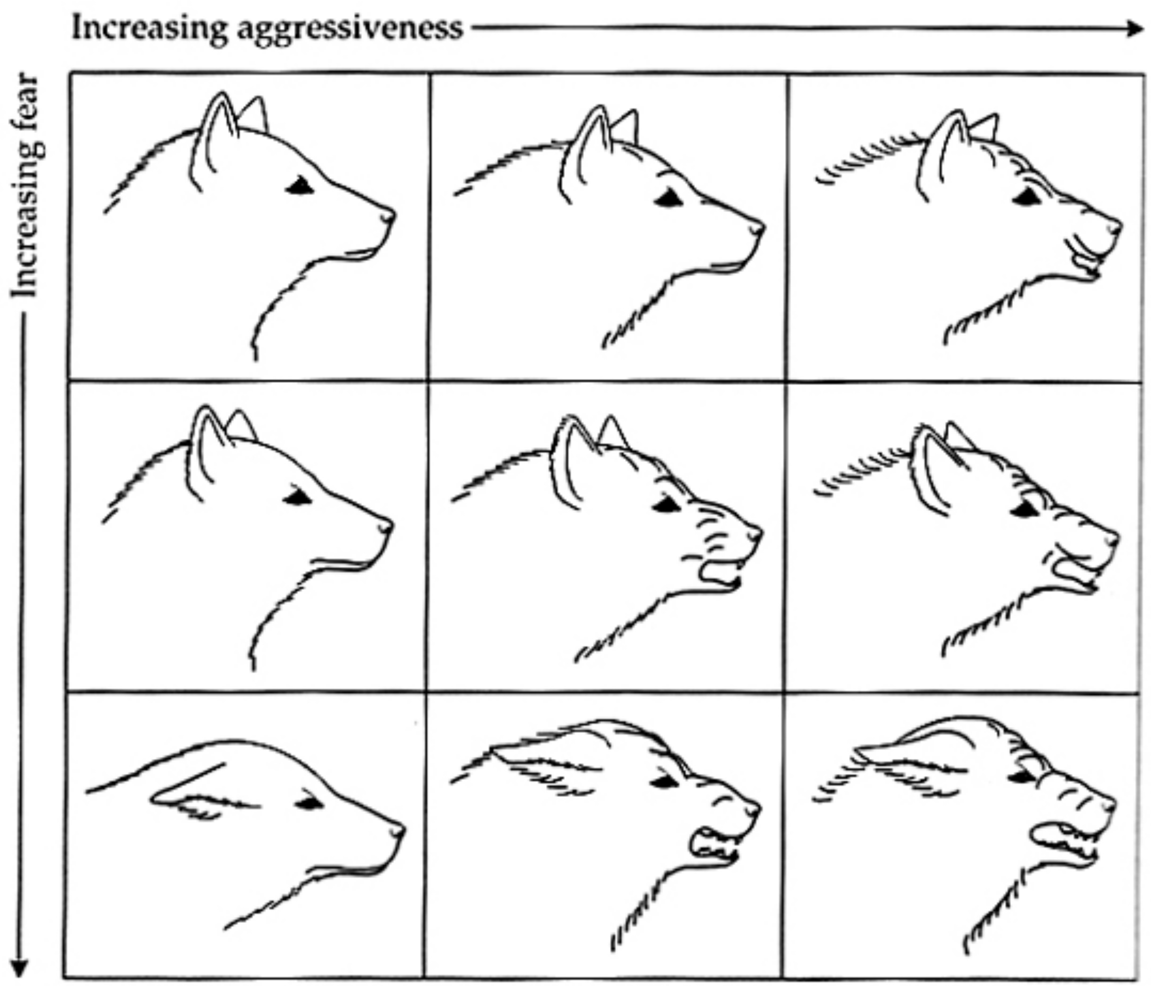
- Expect animals that defend territories to use signals that convey information about range and individual identity
  - McGregor PK 1993 Signaling in territorial systems – A context for individual identification, ranging and eavesdropping. Philos. Trans. Roy. Soc. Lond. B 340:237-244.
- Examples
  - Wolf howls and coyote yells
  - Howler monkeys and gibbons
  - Gecko barks
- When (time of day) should such signals occur? Why?

Intention movements and antithetical displays



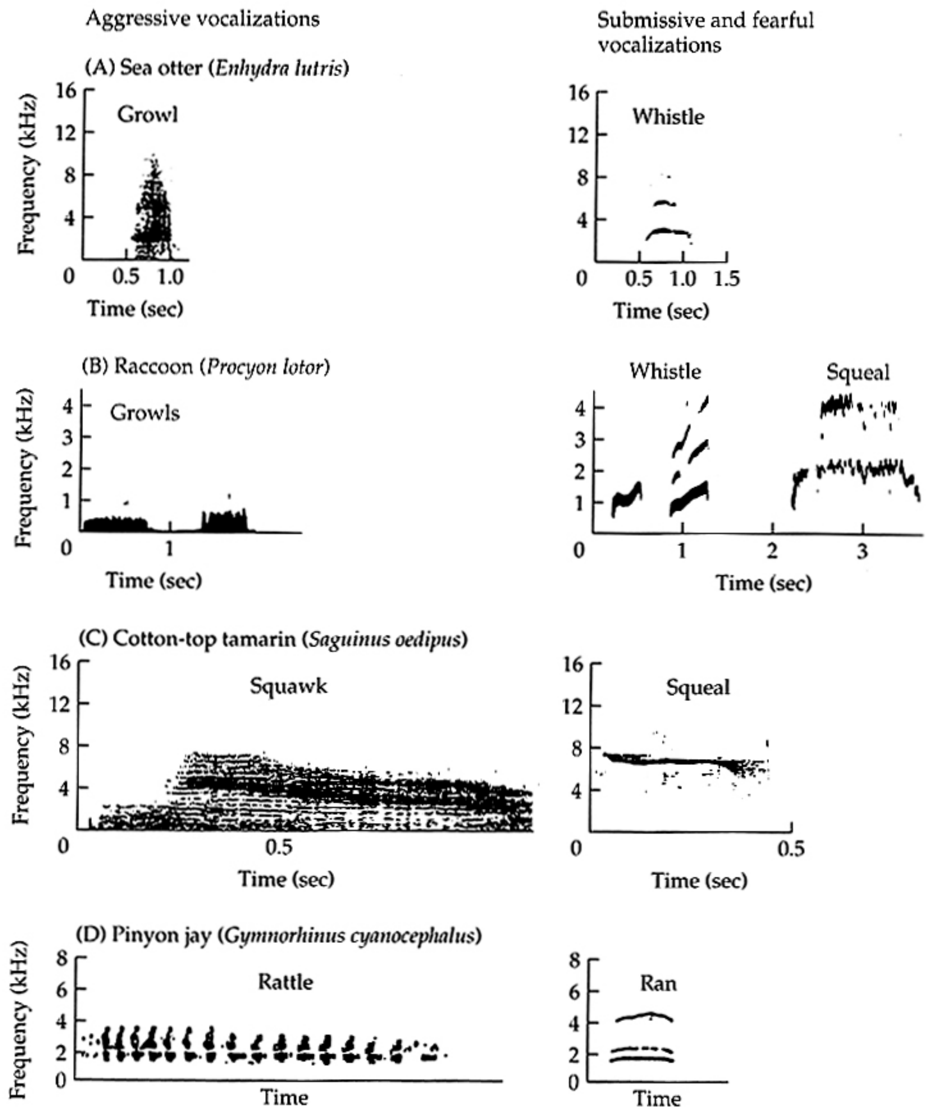
Aggressive displays usually reflect attack preparation movements

Motivational conflict in wolves



Antithetical vocalizations

Aggressive:
Broad band,
Low frequency



Submissive:
Tonal, high
frequency

Morton's motivation-structure "rules"