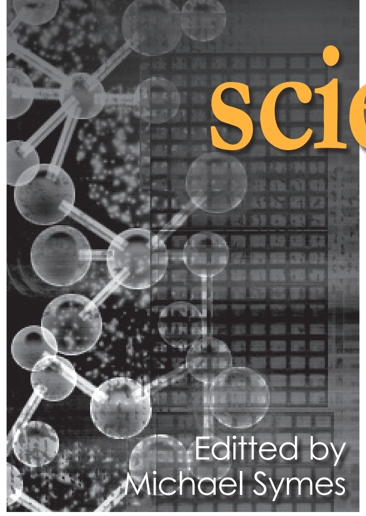


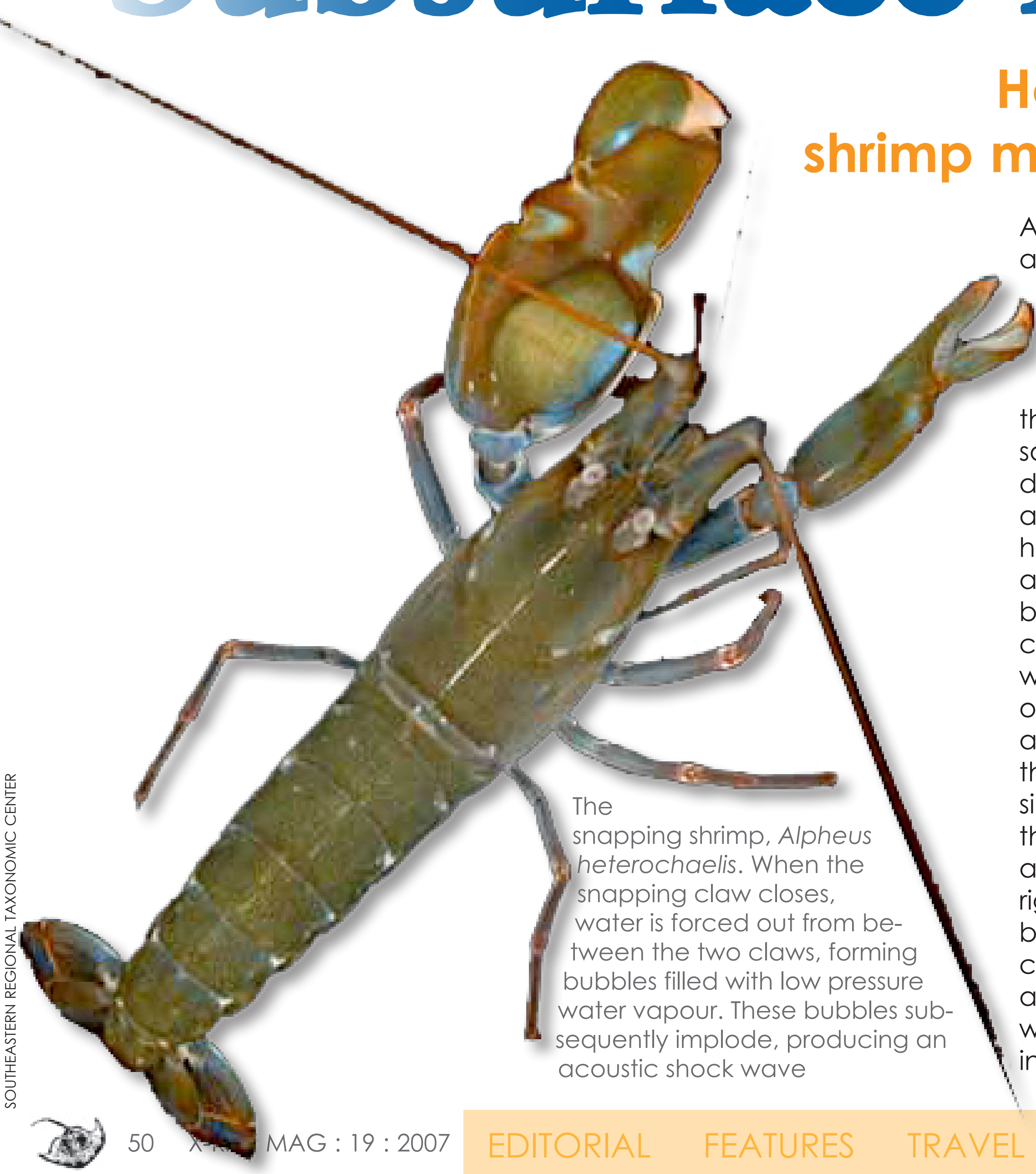
Text by Michael Symes
Shrimp images courtesy of
Southeastern Regional Taxonomic Center

Snapping Shrimp Sound
(link to waw-file)

SOUTHEASTERN REGIONAL TAXONOMIC CENTER

Subsurface Noise

How the snapping shrimp makes itself heard



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The snapping shrimp, *Alpheus heterochaelis*. When the snapping claw closes, water is forced out from between the two claws, forming bubbles filled with low pressure water vapour. These bubbles subsequently implode, producing an acoustic shock wave

As we said in our previous issue, although you might expect the oceans below the surface to be a quiet and still place, they are far from being so.

Submerged hydrophones show that there is a cacophony of sound, which arises from many different sources, both natural and anthropogenic i.e. made by humans. Previously, we looked at the sounds made under water by the marine mammals, especially the songs of the Humpback whale. Although these songs are often very harmonious and pleasant even for humans to listen to, there is also a lot of what we consider just plain noise. If we ignore the anthropogenic noises such as those made by ships and oil-rigs, and the natural noises made by waves and surf, earthquakes, calving icebergs, etc, there is still a considerable amount of noise, which emanates from the aquatic invertebrates and fishes.

Source of the noise

Among the more than 25,000 species of living fish, it is claimed by Dr Rodney Rountree of the University of Massachusetts, USA, that there are more than 700 known vocal fish species in the world. It is not only in the tropical waters that these vocal fishes are to be found. More than 40 species exist in the cool waters around Cape Cod, for example, including the toadfish, sea robin and the striped cusk-eel. The cusk-eel produces croaking sounds of between 500 and 1800 Hz, and the toadfish, *Porichthys notatus*, produces a humming noise at 80 – 100 Hz, which is so loud that it can even be heard on the shore. Even the male haddock, *Melanogrammus aeglefinus*, advertises for a mate using a series of increasingly rapid low thumps.

So, all these fish can be very noisy indeed but how do they actually produce their sounds?

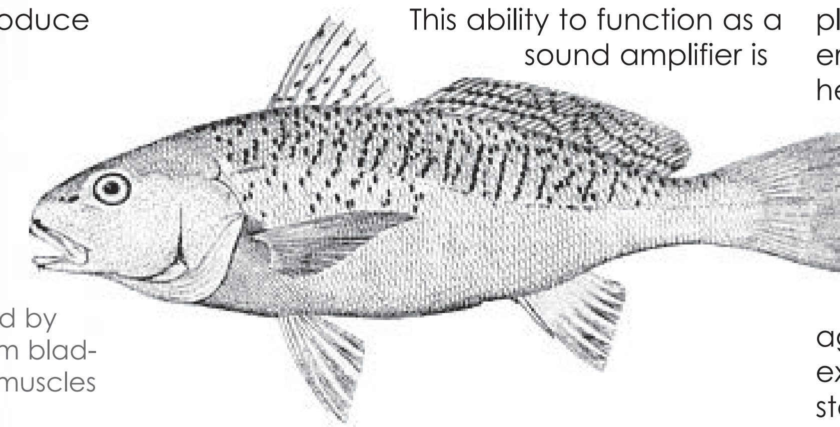
Sound production in fishes

Some fish noises from the Croakers (*Sciaenidae*) are made by muscles that stimulate the animal's swim bladder, which then amplifies the sound. The toadfish, mentioned above, rapidly contracts muscles in its swim bladder at 100 times per second to produce the loud humming. Other fish, for example the Grunts (*Pomadasyidae*), grind teeth close to their pharynx, the sound from which again is amplified by the swim bladder.

The swim bladder or, more accurately, the gas bladder, is a gas-filled sac located in the dorsal region of the fish. It contributes to the ability of the fish to control its buoyancy, and thus enables it to stay at a given depth. It also enables it to ascend or descend without swimming, and thereby conserving energy. Fish like the sole, though, who live on the sea bed, don't have swim bladders.

This ability to function as a sound amplifier is yet another example of an organ developed by evolutionary forces for one purpose, that of efficient swimming, becoming available to use for another, that of amplification of sound. Gas bladders are evolutionarily related to lungs.

Noisy though the fishes and aquatic mammals are, it is perhaps the invertebrates that are the greatest noise makers of them all.



Atlantic croaker, *Micropogonias undulatus*. The croakers and drums characteristically produce a drumming sound by vibrating their swim bladders with special muscles

NOAA

Fish farting

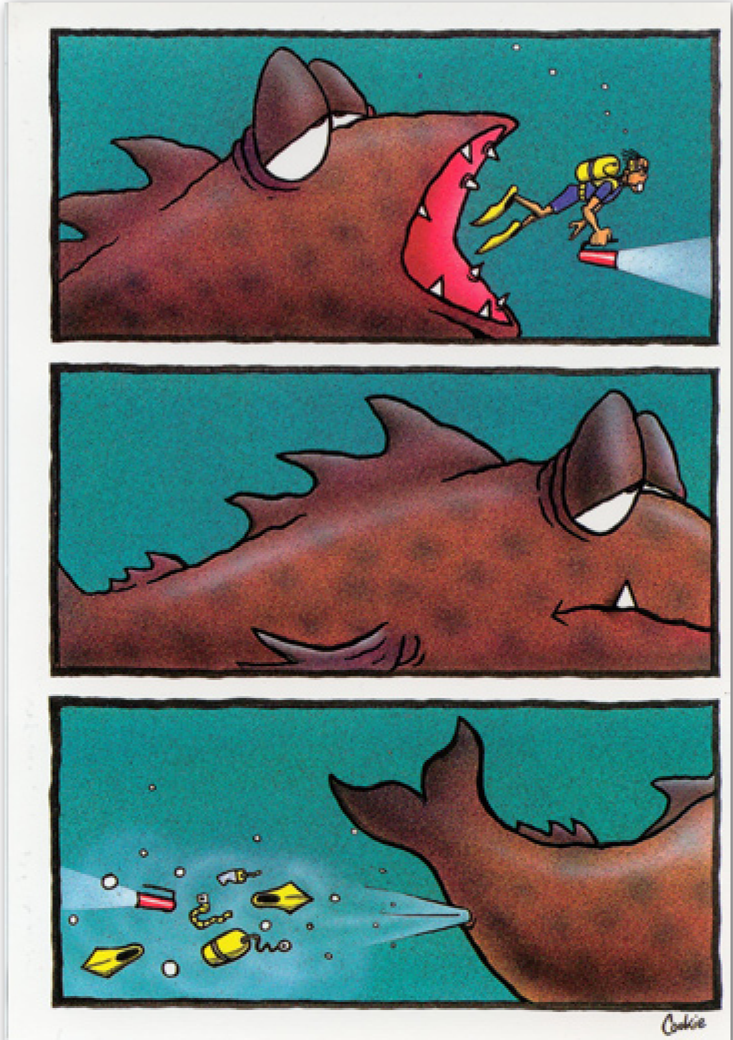
At night, herrings squeeze bubbles out of their swim bladders through an anal pore. The sounds are distinctly fart-like. As they tend to 'fart' more in the company of others it would appear that they play a social function! Hm! However, they may perhaps use the sounds to ward off predators.

Most marine invertebrates produce sound by stridulation i.e. the rubbing together of two parts of the body, just like grasshopper

The noisy invertebrates

Among the marine invertebrates, the crustacea are those that employ strong sound signals in several different ways. We are talking here of the crabs, lobsters, shrimp, etc. Most marine invertebrates produce sound by stridulation i.e. the rubbing together of two parts of the body, just like grasshoppers do on dry land by rubbing their hind legs against the leathery forewings. An example of this is the spiney lobster, *Palinurus elephas*, which rubs its attennae together to produce

On another 'note'...



Postcard and T-shirt motif by cartoonist Simon Cooke. Check out his hilarious other designs at **www.thecartoonery.com**

At 30 ms-1 (over 100 Km/h), the speed of a jet is so great that it more or less rips holes in the water, forming bubbles filled with low pressure water vapour.

a grating sound. Male fiddler crabs can also produce sound by striking various parts of their body with their enlarged claw, with *Uca rapax* producing rapping sounds at between 300 Hz and 600 Hz.

But probably the most noisy one of them all is the snapping shrimp, which produces sound in a quite different, and unique, way.

Snapping shrimp

The snapping shrimp, *Alpheus heterochaelis*, is a member of the *Alpheidae*, a diverse family, which is distributed world-wide. There are more than 600 species within some 38 genera. Snapping shrimp are common inhabitants of coral reefs and oyster reefs. Not only do they inhabit tropical and temperate waters they can, like *Betaeus*, also live in cold seas, and even in freshwater caves (*Potomalpheops*). The sounds of the snapping shrimp can thus be heard in many places all over the world's oceans, and is the dominant sound of the background noise. Snapping shrimps are capable of drowning out submarine sonar and seriously interfering with military and scientific sonar used to detect underwater objects. The noise is so great that hostile submarines can use colonies of snapping shrimp in which to hide.

In all species of snapping shrimp, both males and females have one large "snapper claw" used primarily to capture prey. It is this claw, which can be up to half of the body size, that produces the powerful sound. It has to do with the extremely high-speed closure of the snapper claw, which produces cavitation. It is not the sound from the two claw halves clashing together.

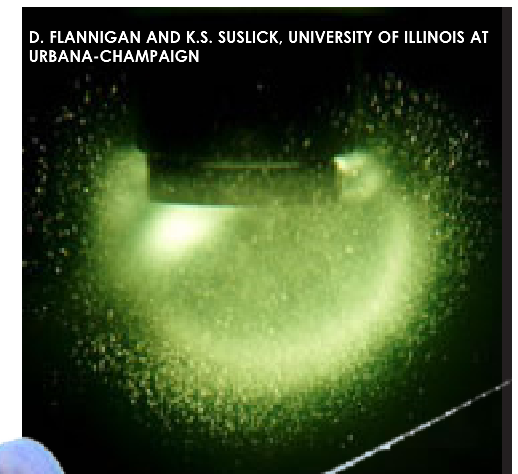
Cavitation

When the snapping claw closes, water is forced out from between the two claws, and a high speed water jet is produced. At 30 ms^{-1} (over 100 Km/h) the speed of the jet is so great that it more or less rips holes in the water, forming bubbles filled with low pressure water vapour.

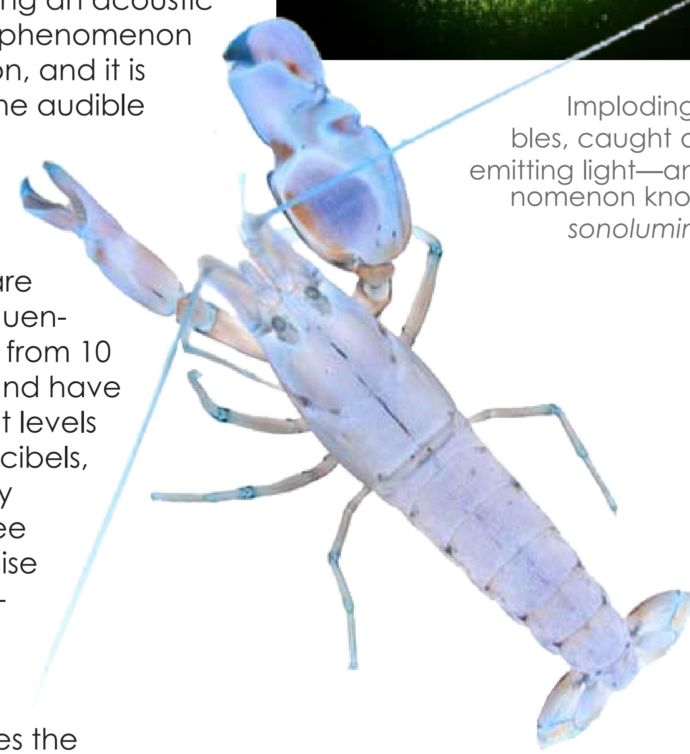
These bubbles subsequently implode, producing an acoustic shock wave. This phenomenon is called cavitation, and it is this which gives the audible click or snap the duration of which is less than 1 ms. The sounds created are in a range of frequencies of anywhere from 10 to 200 000 hertz and have been recorded at levels as high as 200 decibels, which is extremely loud. However, see box regarding noise measurement under water.

Towards the end of the implosion of the bubbles the temperature of the vapour within the, now very small, bubbles can be up to several thousand K, with a pressure of hundreds of atmospheres. Light, known as sonoluminescence, can also be produced.

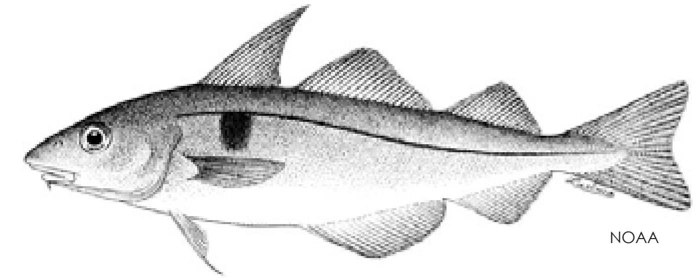
Due to these extreme conditions within the small bubbles cavitation is, in general, undesirable when it occurs in connection with ships, for it can cause serious damage to their propellers and hulls. It is obvious, then, that this is a very powerful weapon for the shrimp, for the cavitation generates acoustic pressures that can stun, and even kill, crabs, fish and worms.



Imploding bubbles, caught on film emitting light—an phenomenon known as *sonoluminence*



Even the male haddock, *Melanogrammus aeglefinus*, advertises for a mate using a series of increasingly rapid low thumps



The decibel

A decibel is approximately the smallest change in the volume of sound that can be detected by the human ear.

Most people are familiar with the concept of the decibel as a measure of sound levels under normal conditions in air. We seldom appreciate, though, what an extremely sensitive organ the ear is.

Humans can detect sound waves of extremely low intensity. The faintest intensity that can be detected by the normal human ear is 10^{-12} Wm^{-2}, corresponding to a sound which displaces air particles by 10^{-11}m. This is an incredibly small amount.

Humans can detect sound waves of extremely low intensity.

In comparison, the radius of an atom is typically 10^{-10}m, i.e. some ten times bigger. This faint sound is called the threshold of hearing and is the internationally agreed upon reference standard for sound perception in air.

The most intense sound, which the ear can detect without suffering damage, is about 10 Wm^{-2}, which is more than a billion times greater than the threshold value.

In the description of sound we use a logarithmic scale of intensities because the sensitivity of the ear is roughly logarithmic. Thus, to perceive a sound as being twice as loud its intensity must be ten times greater.

The intensity level **I** for a sound of intensity I_1 given in dB is therefore given by the equation:

$$\mathbf{I} = 10 \log_{10}(I_1/I_0) \text{ dB}$$

where I_0 is the intensity of the threshold of hearing, and 10 is the conversion factor from bels to decibels.

A decibel is approximately the smallest change in the volume of sound that can be detected by the human ear.

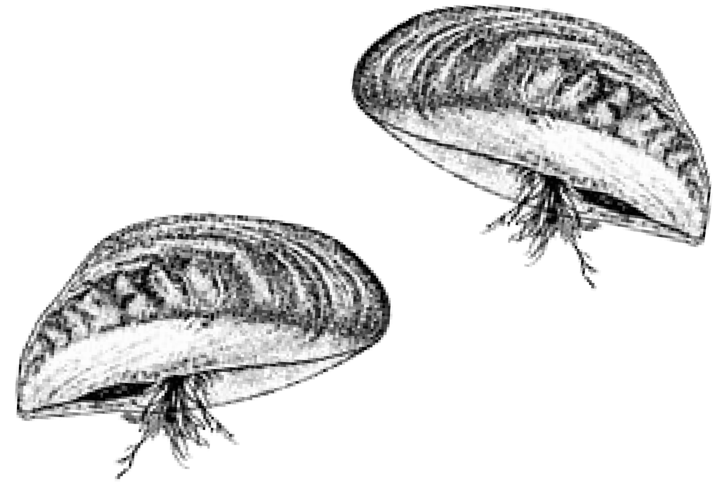
Some typical values for intensity levels **in air** are given below:

Threshold of hearing	0 dB
Whisper	20 dB
Normal conversation	60 dB
Threshold of pain	130 dB
Perforation of eardrum	160 dB

For sound **under water**, a different reference standard is used, which has consequences for the calculation of dB values. It would be too detailed to go into here, but it can be shown that to convert from water into air simply subtract 62 dB from the value in water. So, 200 dB in water would be equivalent to only 138 dB in air which, however, is still well above the pain threshold. ■

PETER SYMES

Fish are known to call out to potential mates with low "grunts and buzzes", produced by wobbling the swim bladder, which is located in the abdomen



A very useful tool

Although the snapping shrimp is the noisiest of them all, contributing to up to 70 dB to the ambient noise level, other crustacea can also use cavitation as a tool. An especially interesting example is the tiny peacock mantis shrimp, *Odontodactylus scyllarus*, which uses cavitation to help break open snails. It first hits the snail with a great force using its front leg, and then half a millisecond later cavitation finishes the job. (See S. N. Patek and R. L. Caldwell, *Extreme impact and cavitation forces of a biological hammer: Strike forces of the peacock mantis shrimp Odontodactylus scyllarus* (2005). Journal of Experimental Biology. 208 (19), pp 3655-3664)

Snapping shrimp use both the water jet and the powerful noise the bubbles make not only to stun prey but also to defend territory and communicate with other shrimp. The force with which the bubbles collapse is so great that prey such as worms, fish or crabs are injured by the powerful blast. Snapping shrimp can also communicate through highly sensitive hairs on their claws that can sense pressure changes caused by the bubbles.

Due mostly to the snapping shrimp, coral reefs are very noisy places. It has been found that this noise, which can be heard many kilometres away, helps young fish find their way home from out in the ocean. Larvae of the cardinal fish and the damsel fish, for example, get carried out to sea by ocean currents. After growing and becoming good swimmers they can then head back to the reef by following the noise.

Other subsurface noise makers

There are many other marine creatures that contribute to the background noise of the oceans. Even the charming seahorses (genus *Hippocampus*) rub two bones together near the top of their heads to give a clicking sound. This behaviour is probably some sort of mating ritual.

As exemplified by the mussel *Mytilus edilus*, barnacles and other molluscs can produce noise when the byssal threads, which attach the mussel to a hard substrate, stretch and break. However, like the sounds from many other creatures, such as the sea urchins, these appear to be contingent noises without any apparent function either as a tool or for communication—although, of course, we can never be sure.

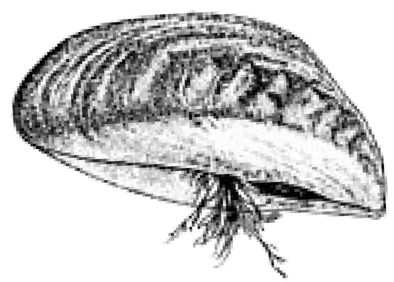
Problems with anthropogenic noise

Like the 'cocktail party effect' where, in spite of the great ambient noise from other peoples' conversations, one can pick out quite clearly what your neighbour is saying, marine animals can sift out the signals that are important to them from the background noise.

However, the increase of noise pollution is having an effect on aquatic creatures. It can disturb their ability to find food and also to find a mate; and it can also cause stress like that induced in humans in an ever increasing noisy society.

Although this noise pollution arises from many different sources much could be done to reduce it. The noise from the propulsion systems of large tankers, could be reduced by using different propulsion systems, for example. And more care could be taken when developing and utilising sonar and similar systems for military purposes. Such developments cost money, of course, a great deal of money. The question is: are we prepared to pay the price to preserve the health of one of our most important resources—the species living in the oceans?

One would hope so, but it is difficult to be optimistic. ■



Byssus threads are long fine silky filaments excreted by several mollusks (particularly *Pinna nobilis*) by which they attach themselves to the sea bed

STEIN JOHNSEN