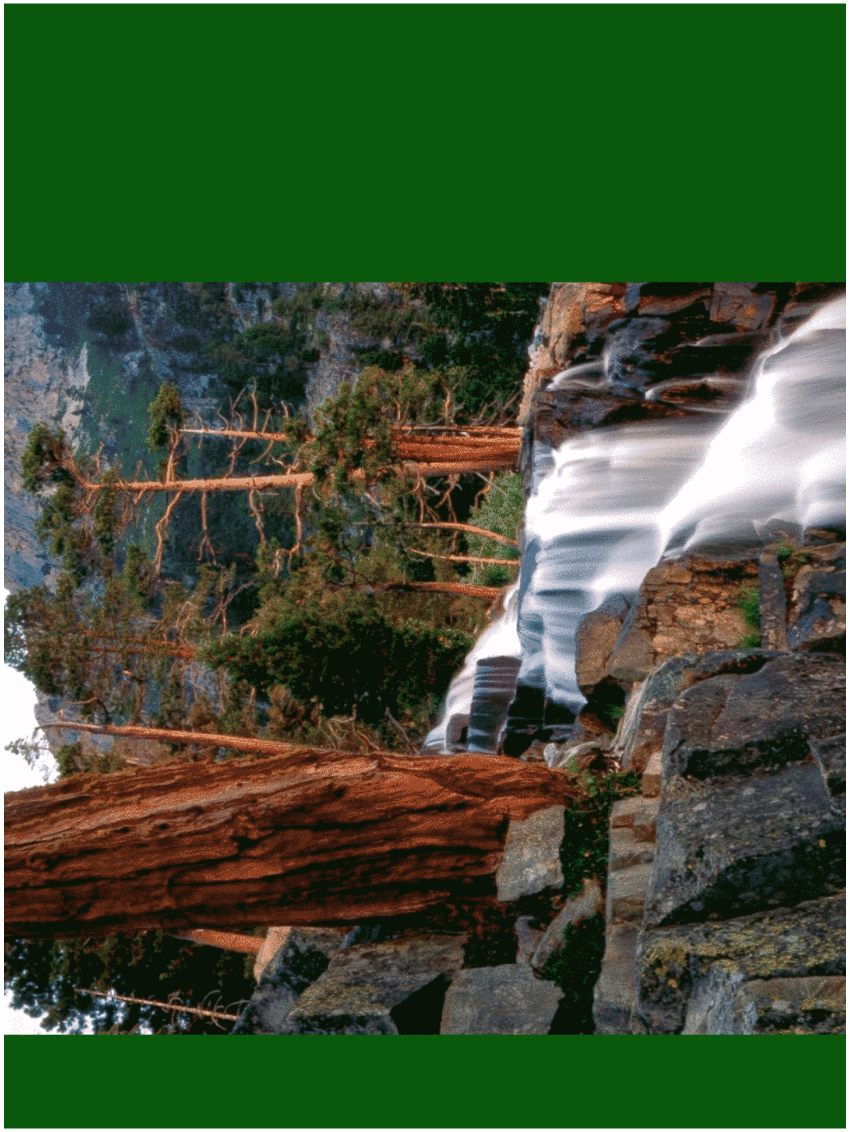
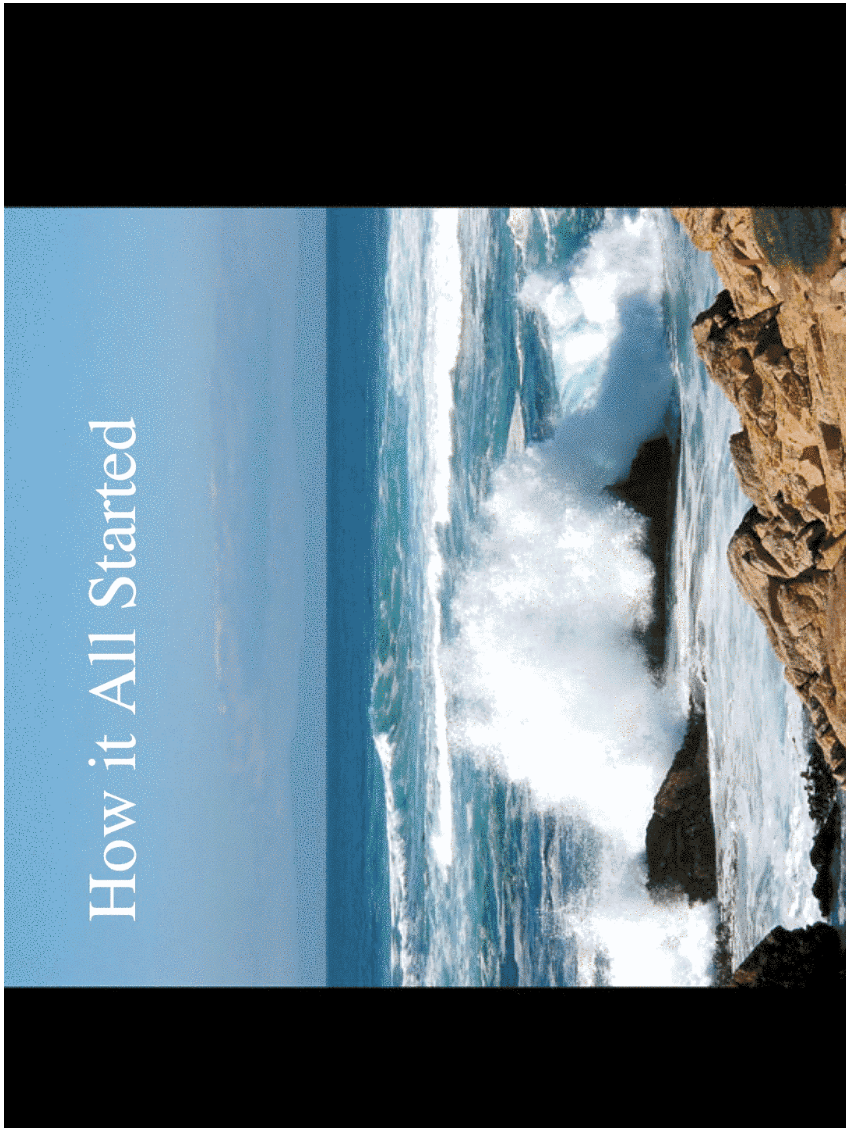
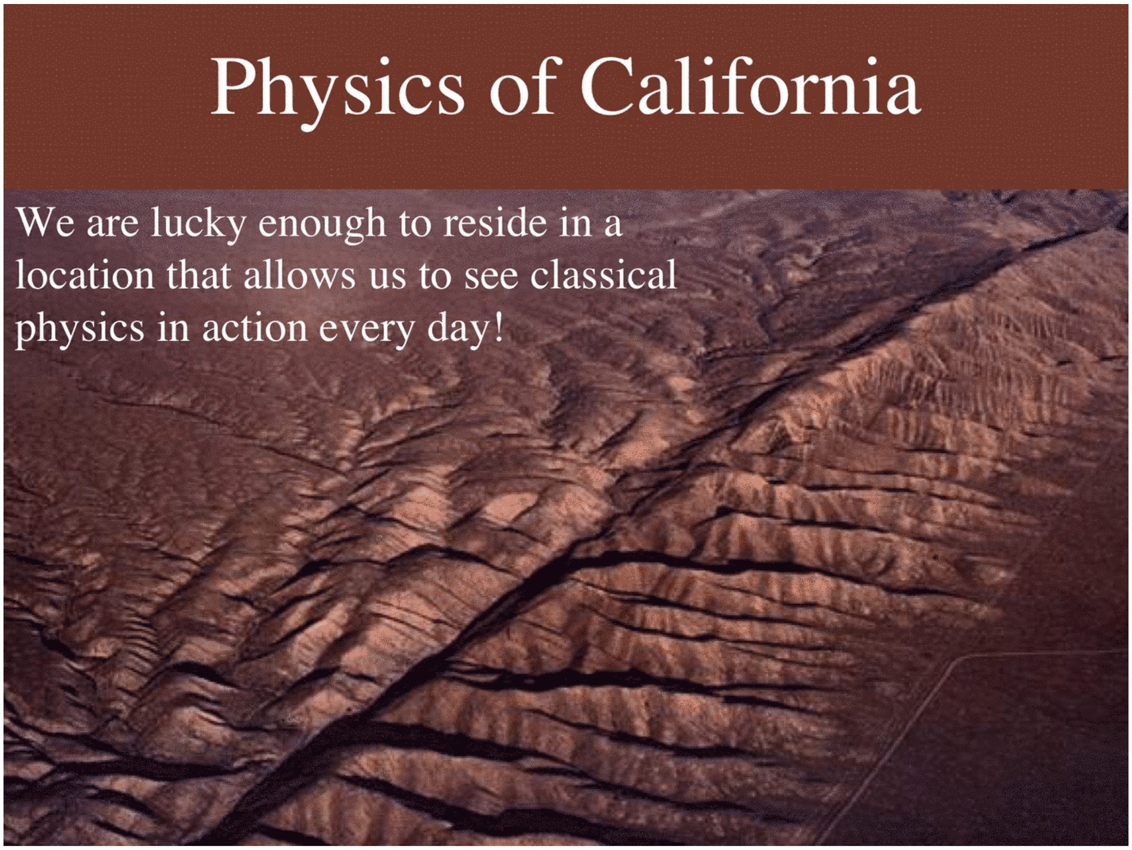


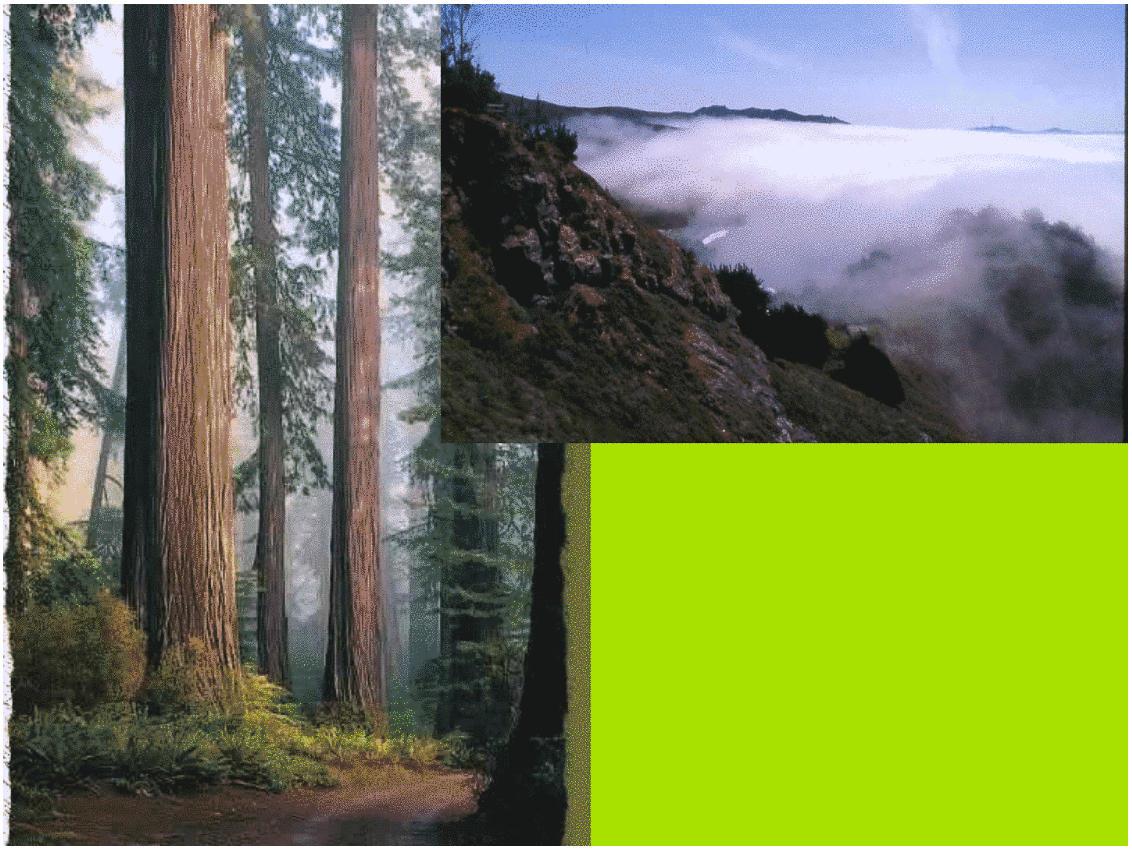


How it All Started



Physics of California

We are lucky enough to reside in a location that allows us to see classical physics in action every day!



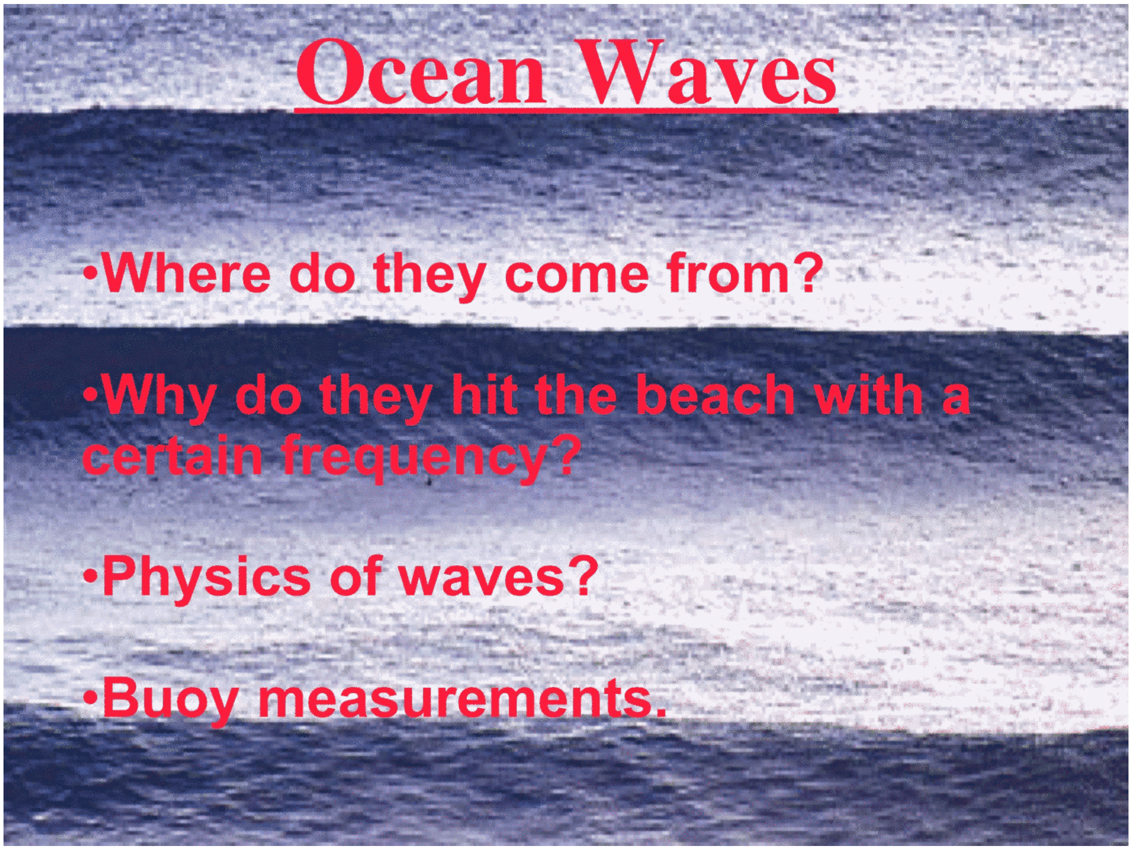
Physics of California

- This course was created in 2004 to offer UCSB physics juniors and seniors a chance to learn classical physics and apply it to the natural world around them.

- The breadth of physics needed for understanding these phenomena and the difficulty often posed by trying to do it “exactly right” forces them to make estimates, carry out dimensional analysis and get the units right.

- These are all crucial skills for a practicing scientist.

- The UCSB physics department has agreed to make this course part of our standard curriculum.



Ocean Waves

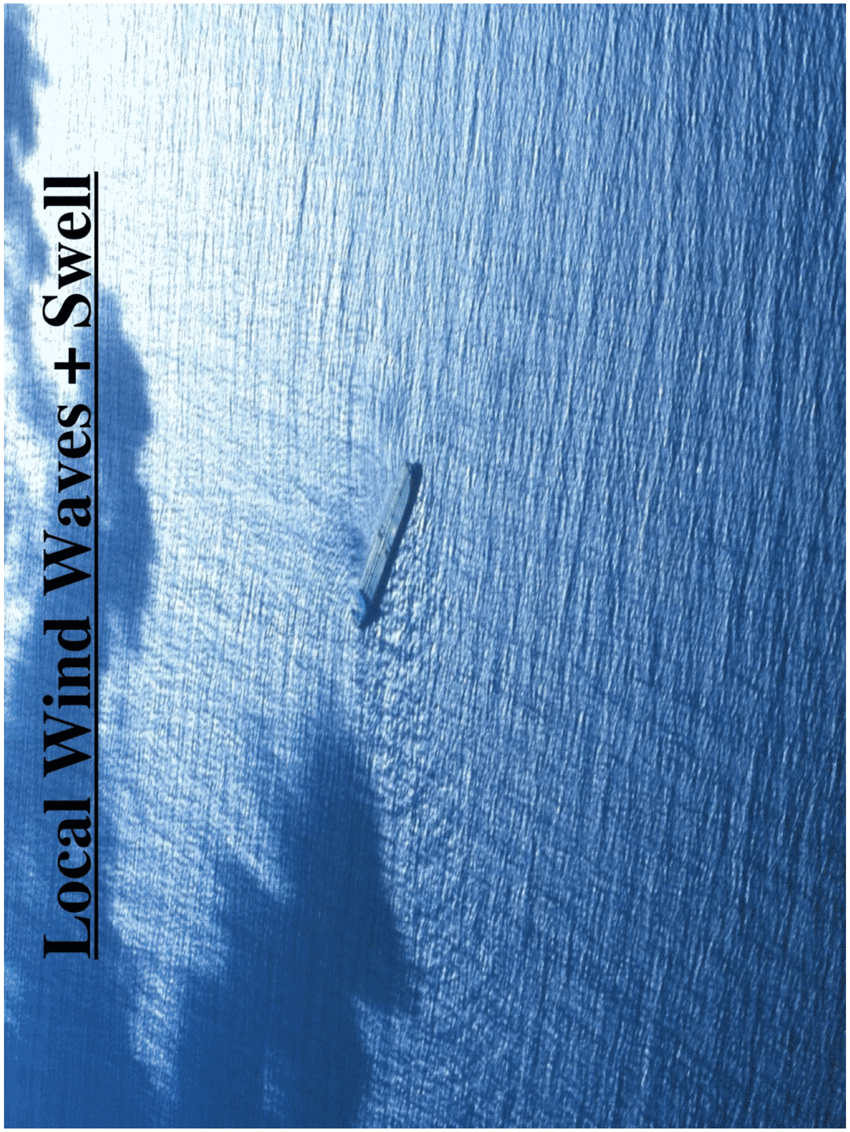
- Where do they come from?

- Why do they hit the beach with a certain frequency?

- Physics of waves?

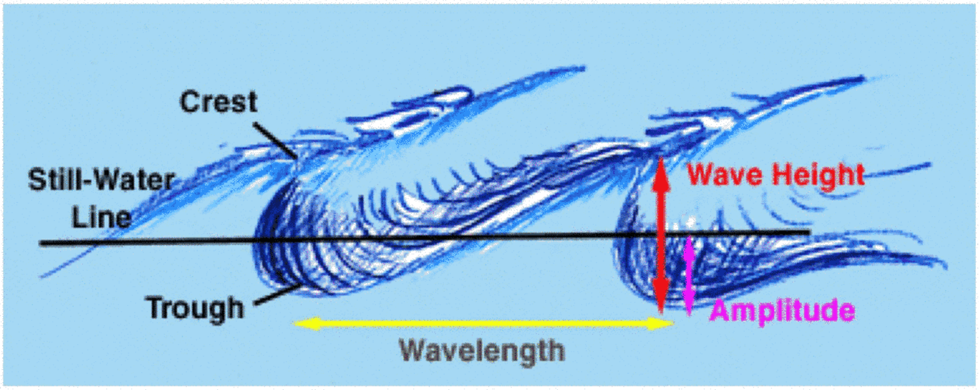
- Buoy measurements.

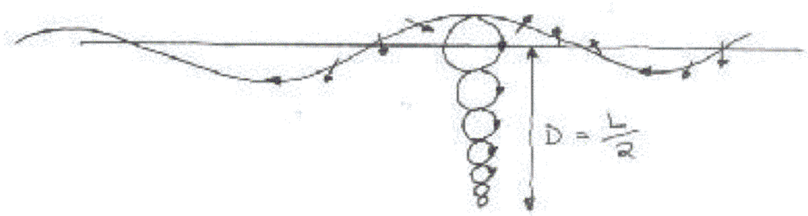
``The Swell’’



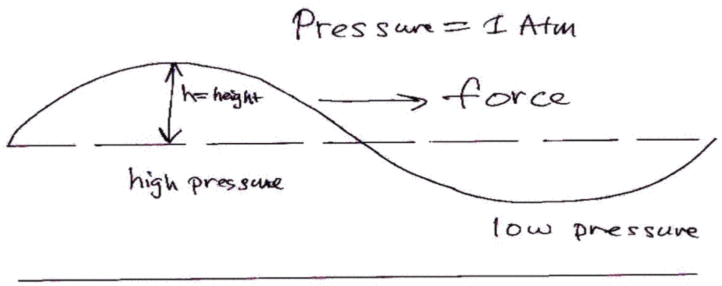
Local Wind Waves + Swell

Description of Waves





Physics of Water Waves

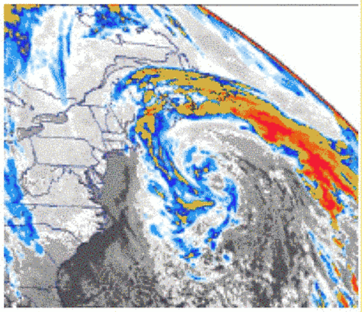


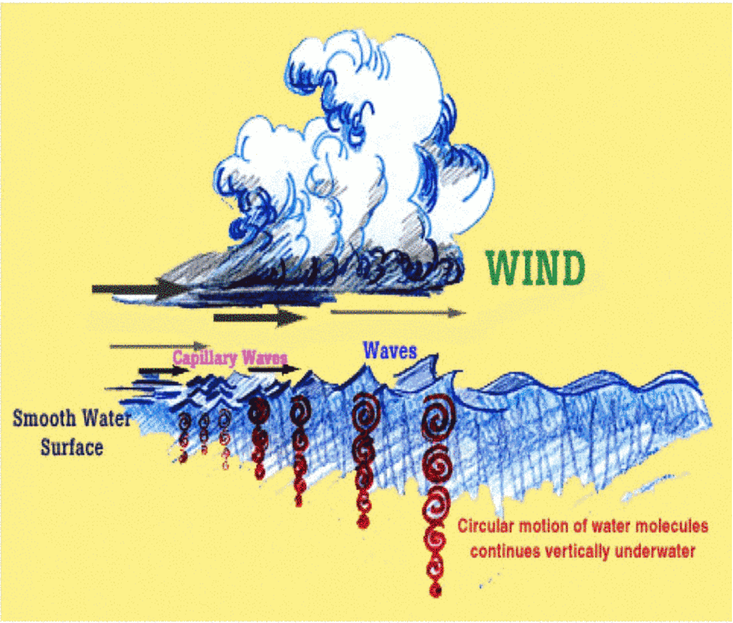
Period-Wavelength relation:

$$\text{Period} = 10 \text{ sec} \left(\frac{\text{wavelength}}{100 \text{ meters}}\right)^{1/2}$$

$$\text{Speed} = 10 \, \frac{\text{meters}}{\text{second}} \left(\frac{\text{wavelength}}{100 \text{ meters}}\right)^{1/2}$$

Birth of Waves





Storm creates mix of wavelengths.

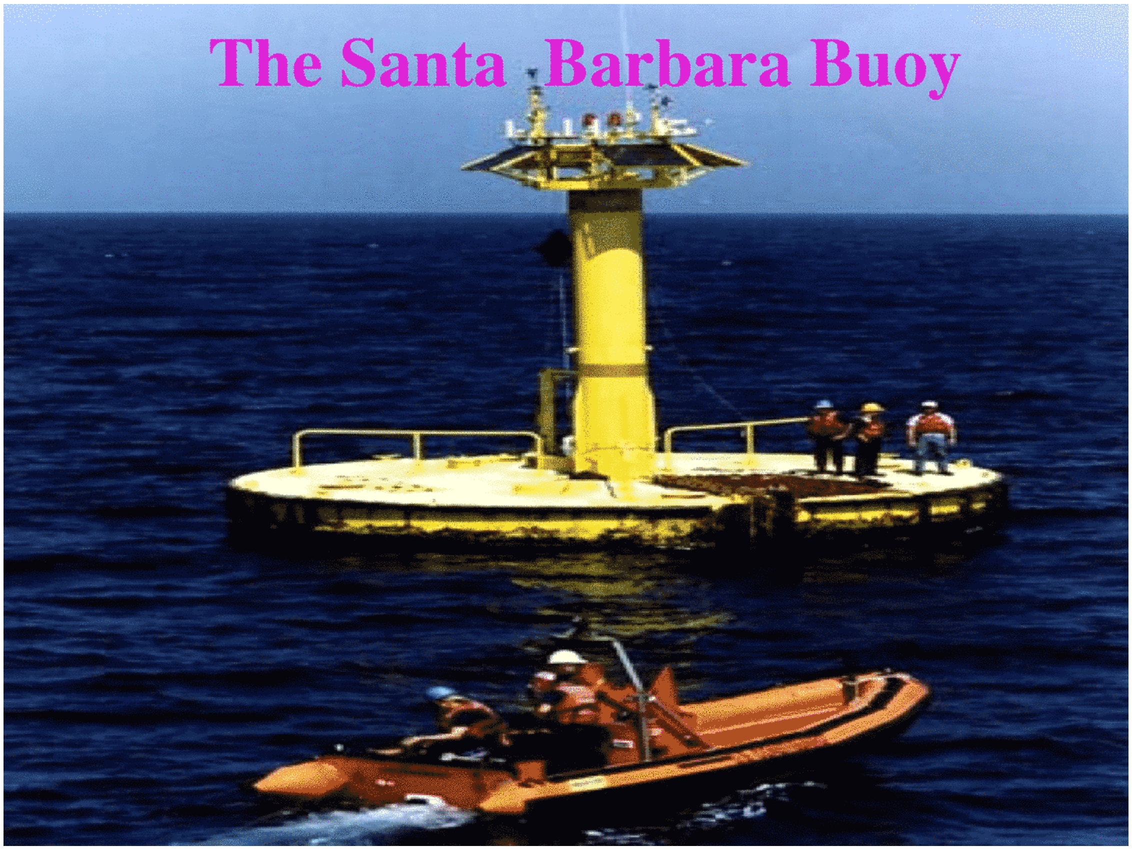
But then why do we see one dominant wavelength??

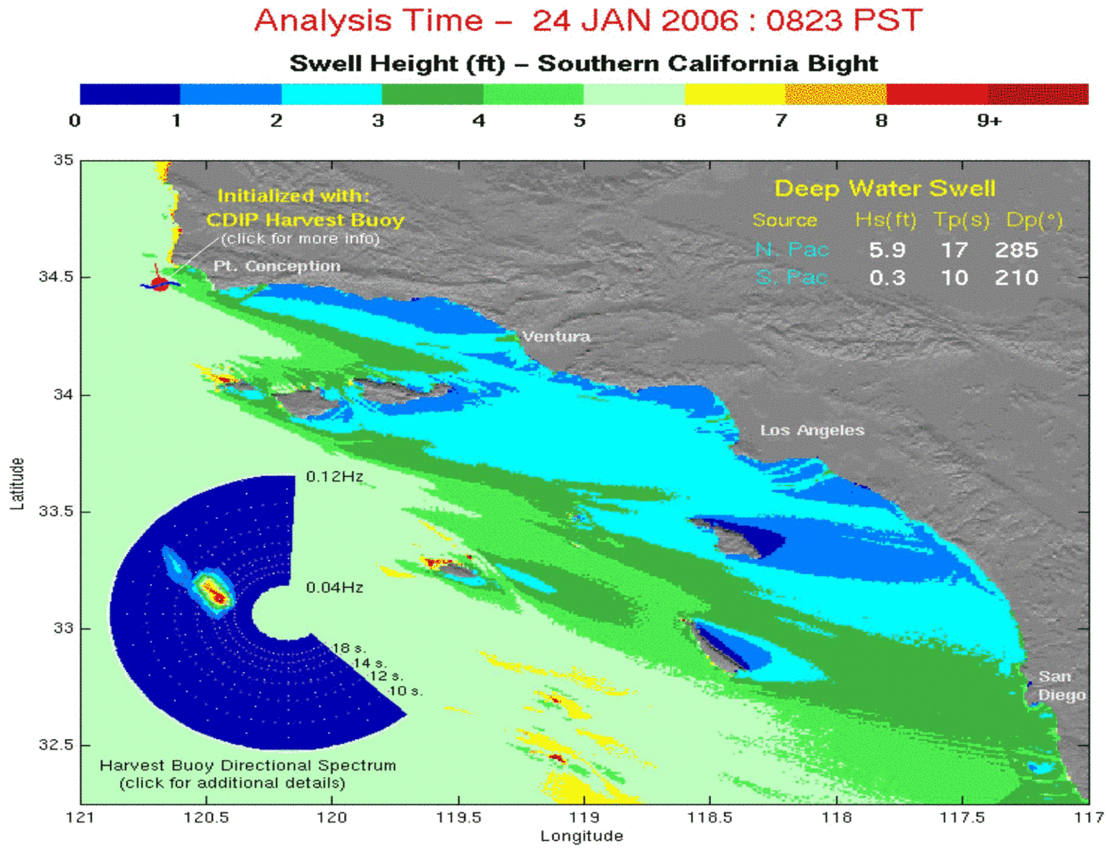
Sorting of Waves by Period

$$\text{Speed} = 10\,\frac{\text{meters}}{\text{second}}\left(\frac{\text{Period}}{10\text{ seconds}}\right)$$

- Longer periods travel faster, so we see them first.
- Observed period gets shorter over time (watch the Weather Channel!)
- Can use this to measure distance to storm!

The Santa Barbara Buoy





Analysis Time – 24 JAN 2006 : 0823 PST

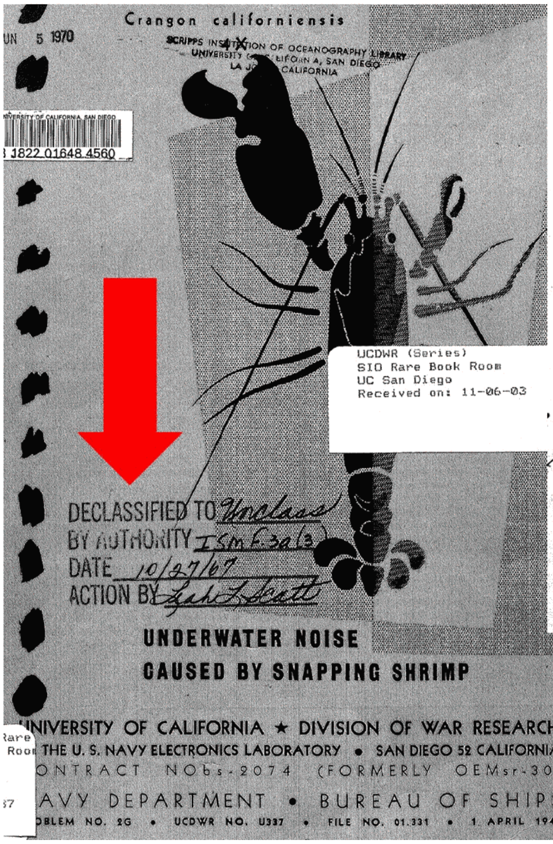
Swell Height (ft) – Southern California Bight

Deep Water Swell

Source	Hs(ft)	Tp(s)	Dp(°)
N. Pac	5.9	17	285
S. Pac	0.3	10	210

Snapping Shrimp

Why is this man concerned?



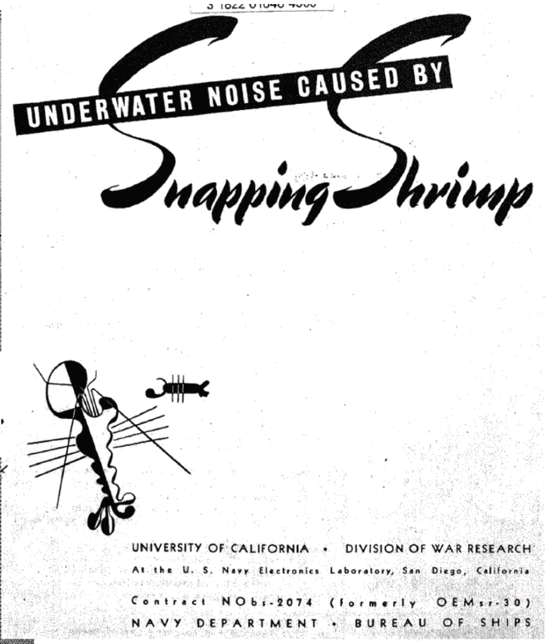
Crangon californiensis

UCDWR (Series)
SIO Rare Book Room
UC San Diego
Received on: 11-06-03

DECLASSIFIED TO Unclass
BY AUTHORITY ISM F 3a (3)
DATE 10/27/67
ACTION BY Leah L. Scott

UNDERWATER NOISE
CAUSED BY SNAPPING SHRIMP

NIVERSITY OF CALIFORNIA ★ DIVISION OF WAR RESEARCH
THE U. S. NAVY ELECTRONICS LABORATORY • SAN DIEGO 52 CALIFORNIA
ONTRACT NObs-2074 (FORMERLY OEMsr-30)
AVY DEPARTMENT • BUREAU OF SHIPS
BLEM NO. 2G • UCDWR NO. U337 • FILE NO. 01.331 • 1 APRIL 1946



UNDERWATER NOISE CAUSED BY
Snapping Shrimp

UNIVERSITY OF CALIFORNIA • DIVISION OF WAR RESEARCH
At the U. S. Navy Electronics Laboratory, San Diego, California
Contract NObs-2074 (formerly OEMsr-30)
NAVY DEPARTMENT • BUREAU OF SHIPS

Major source of noise in shallow regions of the ocean!

Early in 1942 investigations of underwater sounds were begun by UCDWR in the San Diego region. From the beginning of field tests a characteristic crackling noise of great intensity was observed. It was encountered first at various locations off Point Loma and in the San Diego Yacht Harbor and was later found in coastal waters off La Jolla, Oceanside, and other places on the southern California coast. The origin of the noise was shrouded in mystery during the first year of investigation, though considerable progress was made in determining its spectral characteristics and in establishing its presence in local coastal waters over rock bottoms, around piers, and in harbors (Ref. 3).

Early in 1943 it was finally established through laboratory tests of various animals and through field studies in different habitats, that the crackling noise results from the claw snapping activities of certain small crustaceans known as snapping shrimp (Ref.6). The snapping shrimp should not be confused with the common commercial shrimp, which is usually much larger and produces no noise. The sharp "snap" produced individually by these animals has long been known but had hitherto been considered only a biological curiosity and not a source of significant underwater background noise.

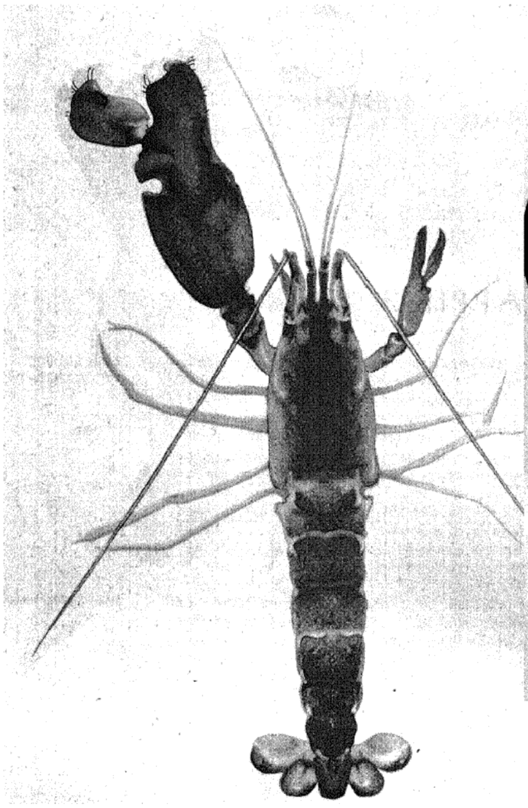
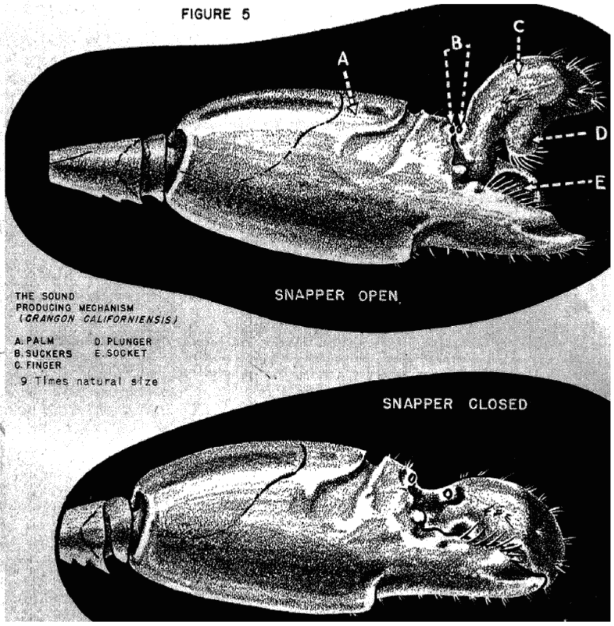
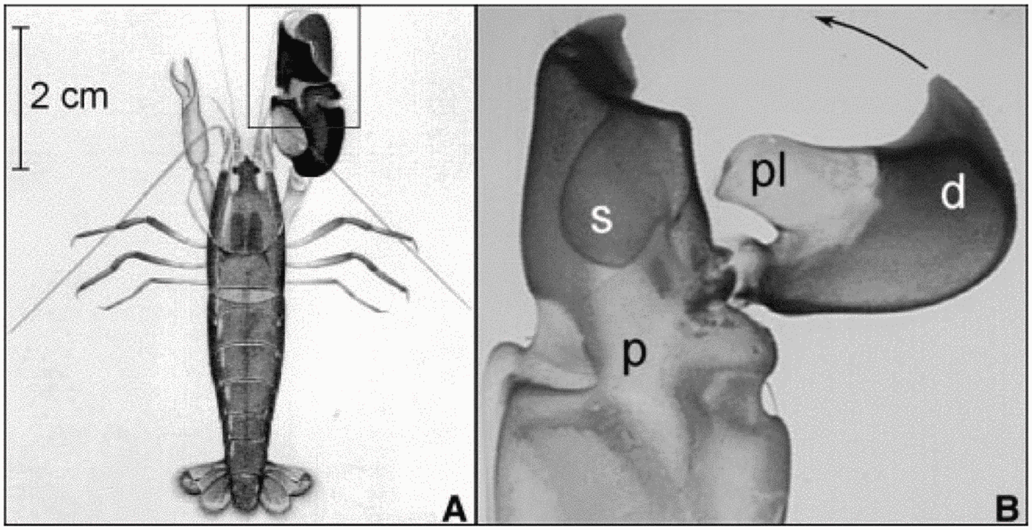


FIGURE 5



What Causes the Sound?



Versluis, Schmitz, von der Heydt & Lohse 2000, Science, 289, 2114

Snapping sound is triggered by closure of the claw, and stuns or kills prey within a few mm. It also creates a water jet that is used to signal nearby shrimp. Until 2000, it was believed that the noise was mechanically caused . . .

Experiments!

Versluis, Schmitz, von der Heydt & Lohse 2000, Nature, 289, 2114

- Seven shrimp attached to a fixed location
- Snap was triggered by touching the claw
- Hydrophone (to measure sound) and 40,500 frames per second camera
- All over in one millisecond!

- The mechanical sound from claw closure is small
- A high velocity (as high as 32 meter/sec=72 MPH!) water jet is emitted from the claw during closure
- This water jet is fast enough to 'cavitate', forming bubbles that reach up to 3.5 mm and later collapse under water pressure to make the sound!
- Bubble collapse happens about 3 mm from the claw, explaining the lethality range.

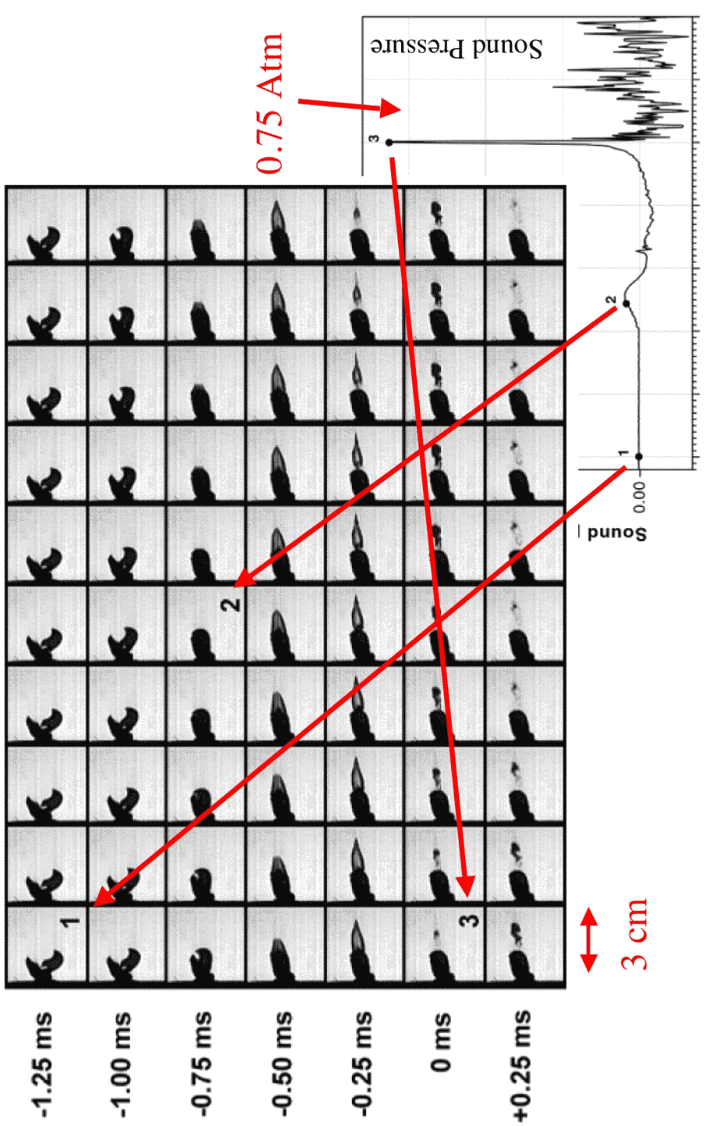


Fig. 2. (A) Hydrophone signal of a snap by an *A. heterochaelis* female measured at a distance *r* = 4 cm. The numbered points correspond to the respective frames in (B). The precursor signal

Versluis et al 2000

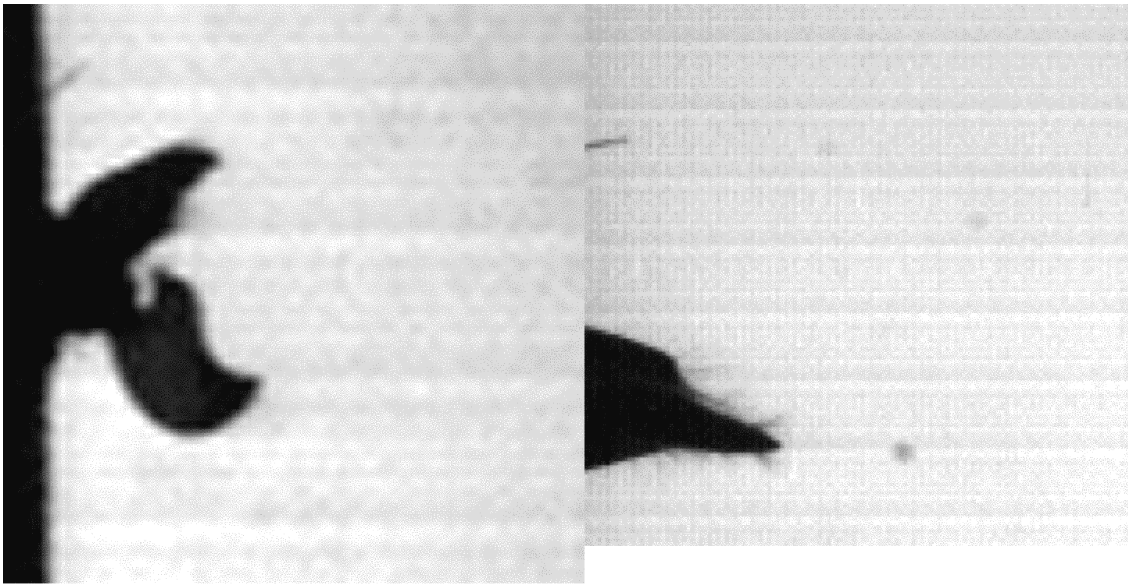
Physics of Cavitation

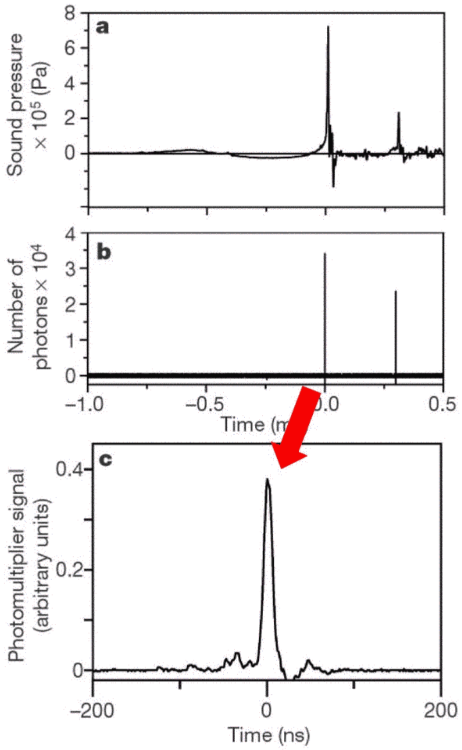
In fluid that is difficult to compress (such as water), the pressure and velocity in two parts of the flow obey “Bernoulli’s principle” (just energy conservation)

$$P_1 + \frac{\rho v_1^2}{2} = P_2 + \frac{\rho v_2^2}{2}$$

The hydrostatic pressure at 10 meters is twice the atmospheric value, or P_1=200,000 Pascals. So, what happens to the flow when the velocity elsewhere, v_2, gets so large that P_2 approaches zero?

$$P_1 = \frac{\rho v_2^2}{2} \rightarrow v_2 \approx (2P_1/\rho)^{1/2} \approx 20 \text{ m s}^{-1}$$





Shrimpoluminescence

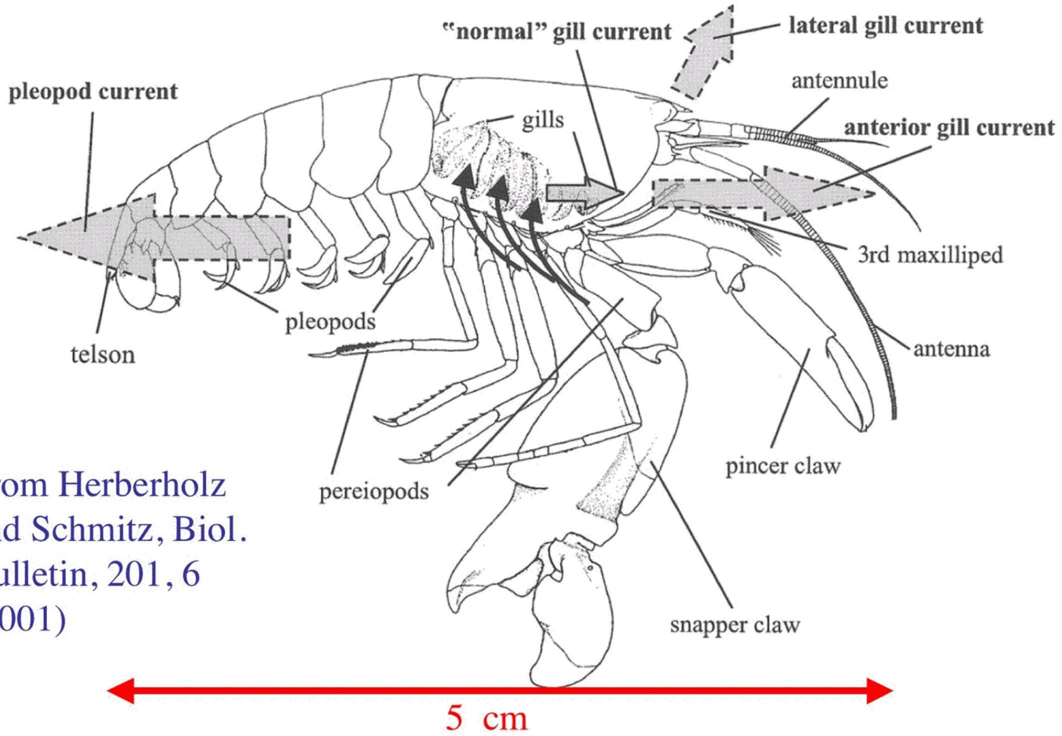
Lohse, Schmitz & Versluis, Nature, 2001, 413, 477

- As in collapsing bubbles in the lab, the vapor gets heated by the rapid compression during collapse.
- In this case, the temperature reached 5,000 K, nearly the temperature at the surface of the sun!
- Duration of the flash is < 10 ns
- Up to 50,000 photons were emitted, though it is not known whether they have any biological significance.

Thank You!


© Dr. Louis Herman

Snapping Shrimp (*Alpheus heterochaelis)*



From Herberholz and Schmitz, Biol. Bulletin, 201, 6 (2001)