

History and Advancement of Biological Oceanography : Global and National Perspectives

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Oceanography: is the study of the earth's oceans and their interlinked ecosystems, geological, chemical and physical processes.

- Geological oceanography: the study of geologic processes in the oceans (plate tectonics, coastal morphology)
- Chemical oceanography: the study of the chemistry of the oceans
- Meteorological oceanography: the study of the interaction between atmosphere and the oceans
- Physical oceanography: the study of the physical attributes of the oceans (temperature-salinity structure, waves, tides, currents)
- Biological oceanography: the study of the flora and fauna of the oceans

Some statistics about world oceans

- Area = 361,100,000sq.km
Volume = 1,370,000,000 cubic km
- **Average depth = 3,796 m (12,451 ft)**
- **Average temperature = 3.9°C**
- **Average salinity = 34.48‰**
- Age = about 4 billion years
- Future = uncertain

Global scenario

- Okeanus (or Oceanus) was the father of oceanids in Greek mythology
- Graphia is Greek for recording or describing
- The word Oceanography is inadequate and probably Oceanology (ology = 'the science of') is more appropriate

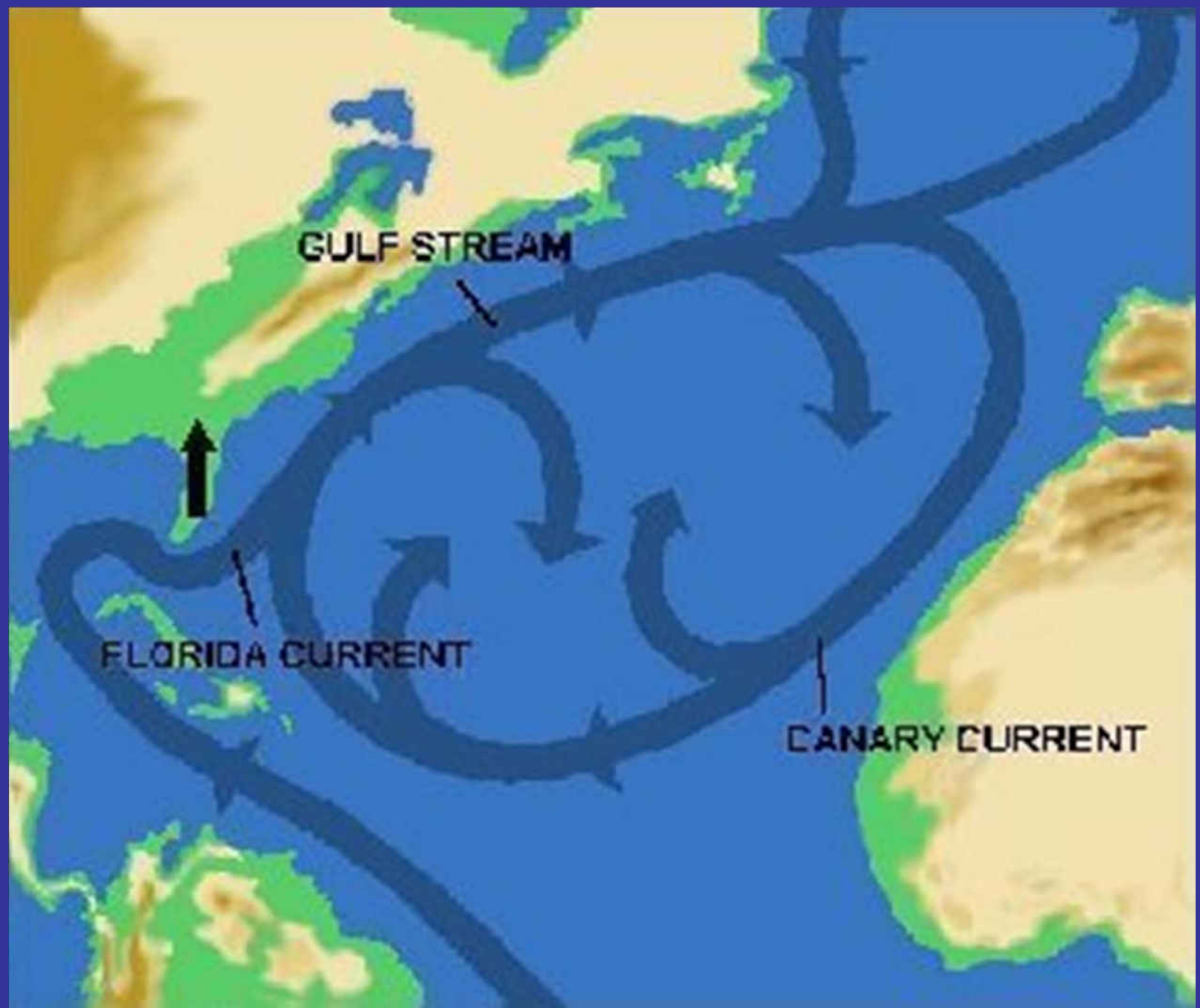


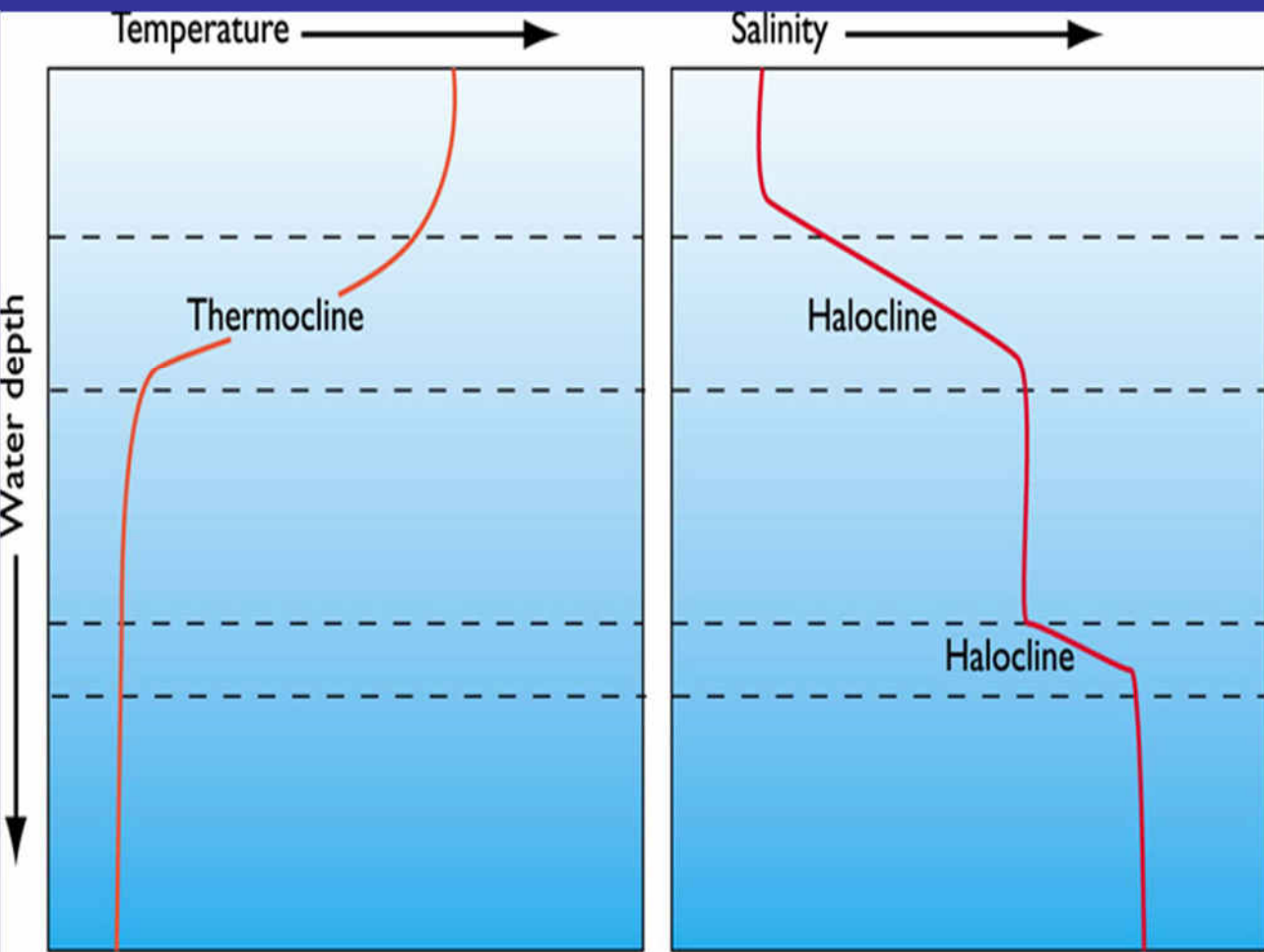
- 325 BC The Greek Pyteas explored coast of England and Norway and developed means of determining latitude from the declination of the North Star. He also proposed a relationship between the Moon and Tides
- 673-735 AD The English monk Bede published *De Temporum Ratione* in which he discussed lunar control of the tides

- Understanding the ocean began with voyaging for trade and exploration.
- The Egyptians and Phoenicians were all skilled sailors
- Cartographers – recorded information about locations and landmarks and currents.

Age of exploration

- 1400s Prince Henry the Navigator – Ocean exploration & navigation
- 1513 Ponce de Leon described the Florida Current
- 1674 Robert Boyle investigated the relationship between salinity, temperature and pressure with depth in seawater
- 1768-79 Captain James Cook's voyages produce extensive data on geography, geology, biota, currents, tides and water temperature of Atlantic and Pacific



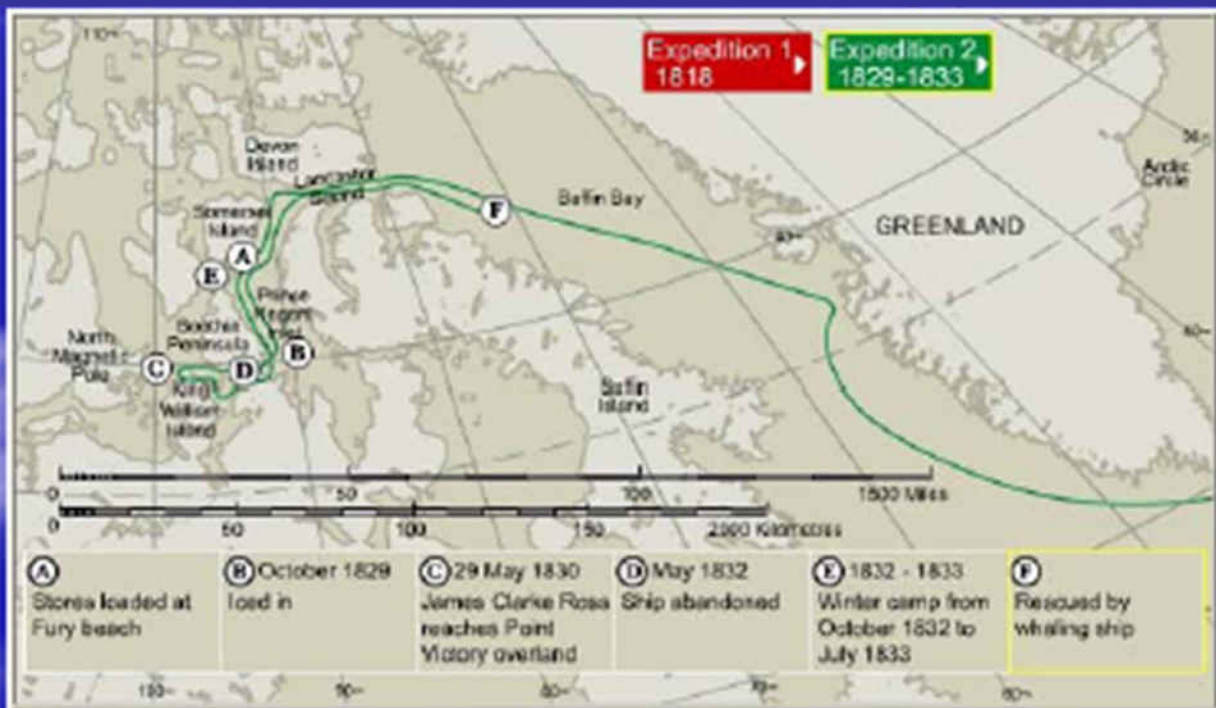


Magellan's voyage



More exploration

- 1817-18 Sir John Ross sails to Arctic to explore Baffin Island and he recovered starfish and polychaete worms from 1800 m thus proving life exists in the ocean depths.



More exploration

- 1820 Alexander Marcet noted that the proportion of chemical ingredients in seawater is unvarying in all the oceans

Forchhammers's Principle: total amount of dissolved salts varies from place to place in oceans but relative proportion of salts remains constant
= chemical equilibrium



In 1839-43:

On HM ships, Erebus and Terror, diatoms were described in Antarctic waters but at that time all life in the sea was under the heading "infusoria" or "animalcules", and the great German protozoologist, C.G. Ehrenberg was convinced that diatoms were animals because the chloroplasts looked like ovaries.

1843:

•It was thought by the British naturalist Edward Forbes, that marine organisms could not exist at depth deeper than 300 fathoms (550 m) . This is in spite of the fact that others had already collected live animals at 750 & 1800m. However Forbes was influential, and most believed him.

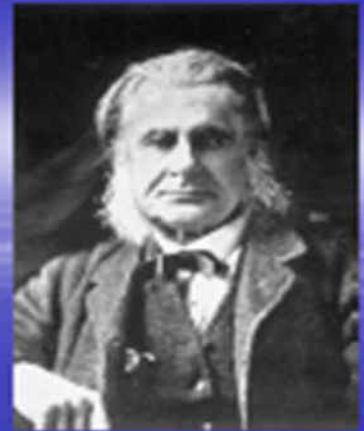


- **CHARLES DARWIN (1809-1881)**
- **HMS Beagle (1831-36)**
- He developed the theory for the development of coral reefs – Subsidence theory.
- Found true in the case of atolls

- **MICHAEL SARS 1850**
- Disproved Azoic theory by describing 19 species that live deeper than 300 f.
- First plankton net was used

1857:

- T.H. Huxley examined sediments collected in the Atlantic and he was struck by how similar under the microscope the ooze looked to the chalk in chalk cliffs. Later he reexamined the sediments (which were in alcohol) and in 1868 noticed a thin layer of mucous like jelly within which were little granules. He said it was protoplasm and was living but had no organs. He named it **Bathybius haeckelii**, and said it crawled on the bottom and was the primordial ooze of life. Thought to be the origin of life and called "Urschleim" (primordial slime) by Germans.



- Later during the Challenger expedition, J. Buchanan disproved the existence of Bathybius. He found that it was precipitate of Calcium sulphate formed due to preserving sea water with alcohol

1860:

Edward Forbes' theory put to rest when a submarine cable was raised from 1830 m and it was covered with animals.

This finding excited the public, and the impetus for the first major oceanographic expedition was started. Plans were made for the Challenger expedition.

- 1868-70 Charles Wyville Thompson on HMS Lightning & Porcupine on summer cruises collected sea life from great depths and stirred public interest in exploring the ocean
- 1871 Fish Commission started in Woods Hole, Massachusetts

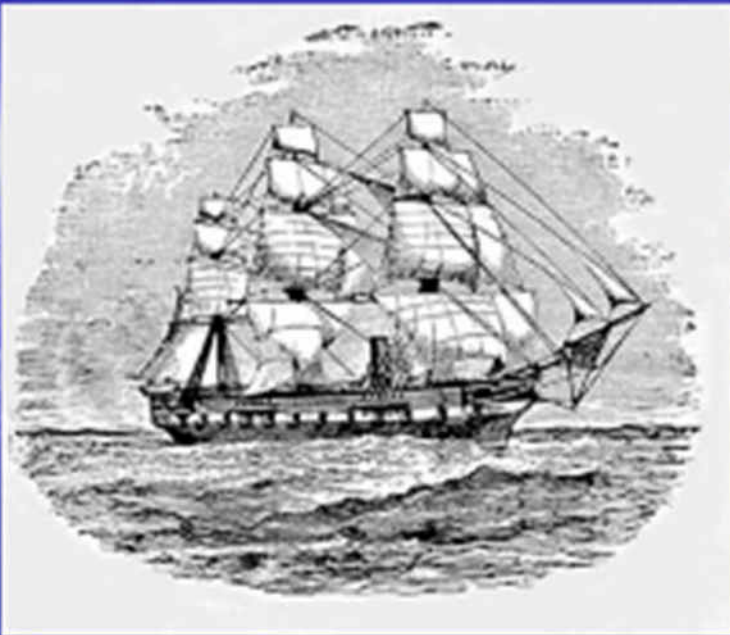
1860's:

Secchi Disc. Invented by Italian astronomer Angelo Secchi while working on the Papal vessel *Immacolata Concezione*.



1872:

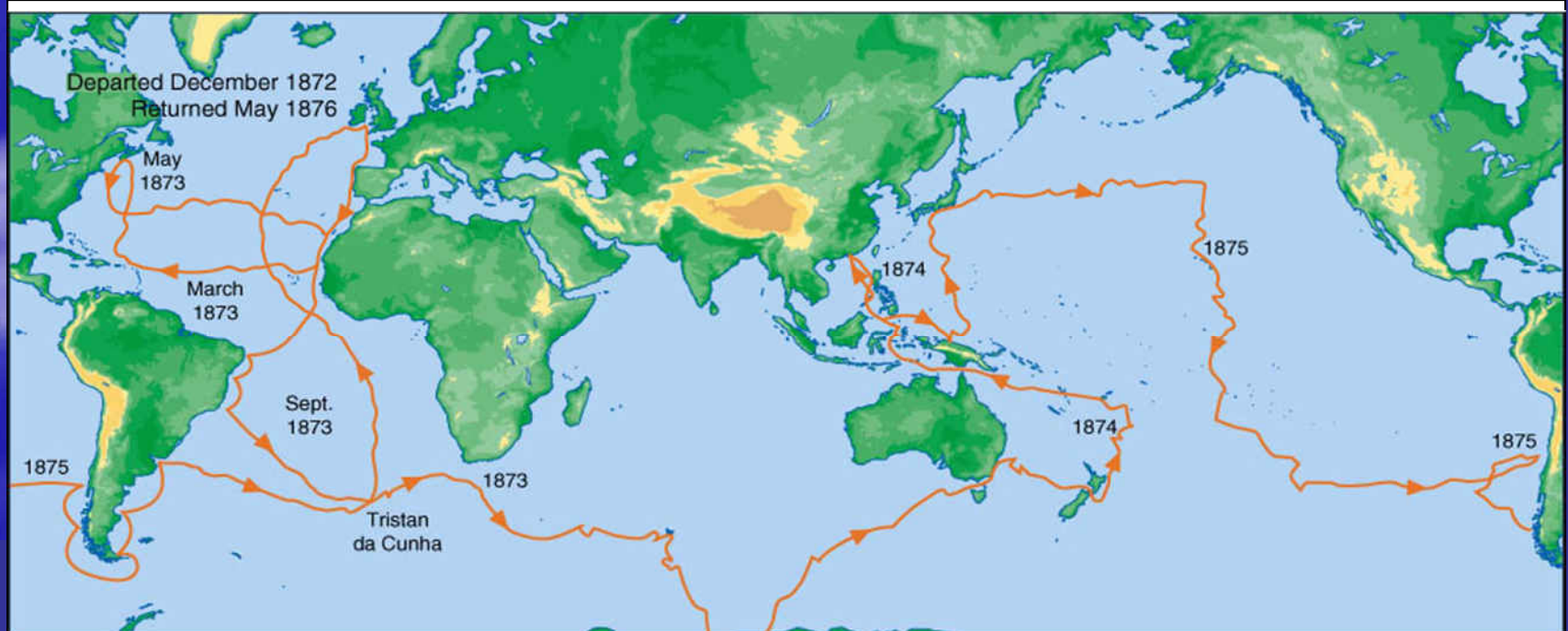
Stazione Zoologica established in Naples by Anton Dohrn 1872



Challenger Expedition

1872

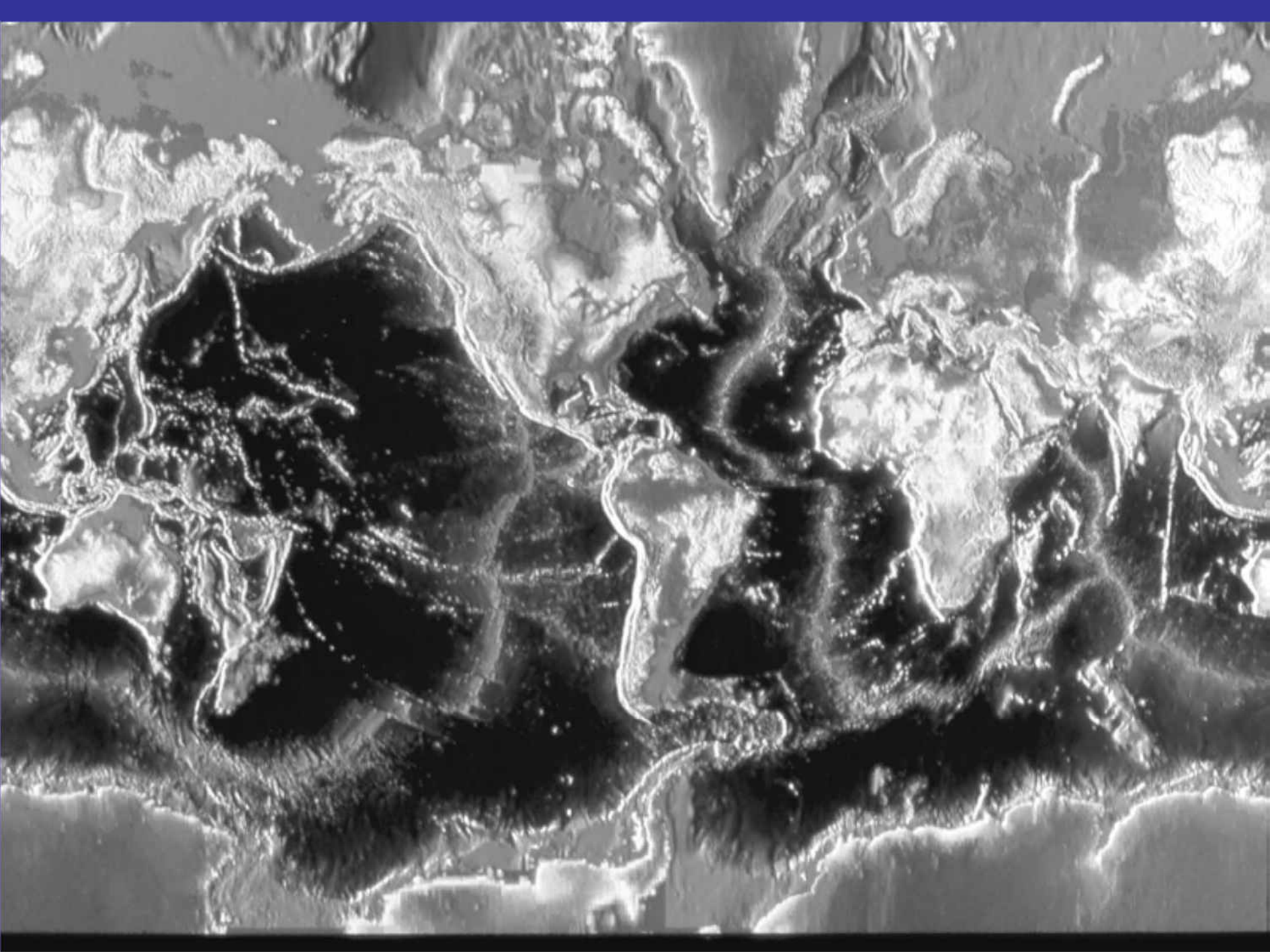
- 226 ft.
- 240 men
- 3.5 yrs
- 5000 new species
- 7000 specimens
- Discovered the Mid Atlantic Ridge.



Challenger Expedition...

- Discovered that life had no depth limits.
- Discovered many new species of plankton.
- Mapped the sea floor.
- Collected and characterized sediments and species.

Success of Challenger stimulated other expeditions by the French, Germans, US and other British investigators.



1885:

Victor Hensen, from Kiel, Germany, coined the term “plankton” (wanderers).

He devised a plankton net which was

QUANTITATIVE and began studies in upper 200 m. He started

studying the distribution of fish eggs in the Baltic because there was interest in why fish stocks fluctuated.



Mills, E. L. 1989.
Biological
oceanography. An
early history
1870-1890.
Cornell Univ.
Press.

- First nets made of cotton unsuitable as it stretched and rotted easily. Next flour- millers cloth. Divided plankton into zoo and phyto.
- The German Plankton Expedition started in 1889. Made a big figure-8 to the equator and back.
- Henson was convinced that plankton were distributed uniformly in the sea. However his cruise showed more plankton in north, cold waters than in tropics.

Early Controversies

- Ernst Haeckel attacked Hensen and said that the tropics must have more plankton than the cold waters because it was warmer and sunnier.
 - He only based this on what is known of terrestrial systems (polar vs rainforest).
 - Haeckel said also that plankton were of little importance and that macroalgae and riverine input were much more important as primary producers in the sea.

The Plankton Paradox

- Henson was puzzled as to why he found more plankton in the colder darker northern waters.
- However he still argued that plankton were distributed homogenously from north to south even though his data contradicted this.
- He asked why did the plankton bloom in the spring rather than in the summer?
- He hired Brandt, who borrowed ideas from the terrestrial scientists. He recalled Liebig's "Law of the Minimum" and he did enrichment experiments and showed availability of nutrients rather than light and temperature controlled productivity of plankton, and the greater availability of nutrients in northern waters was the reason for higher plankton populations there.

- Many nutrients came from runoff, but, they couldn't figure out how plankton far from shore got their nutrients.
- Brandt surmised that bacteria break down the dead plankton, but couldn't figure how the nutrients got from deep to upper water. Gradually, in talking with physical oceanographers, he surmised, that **good mixing** in north but **permanent stratification** in tropics is the reason for the N-S differences in biomass..

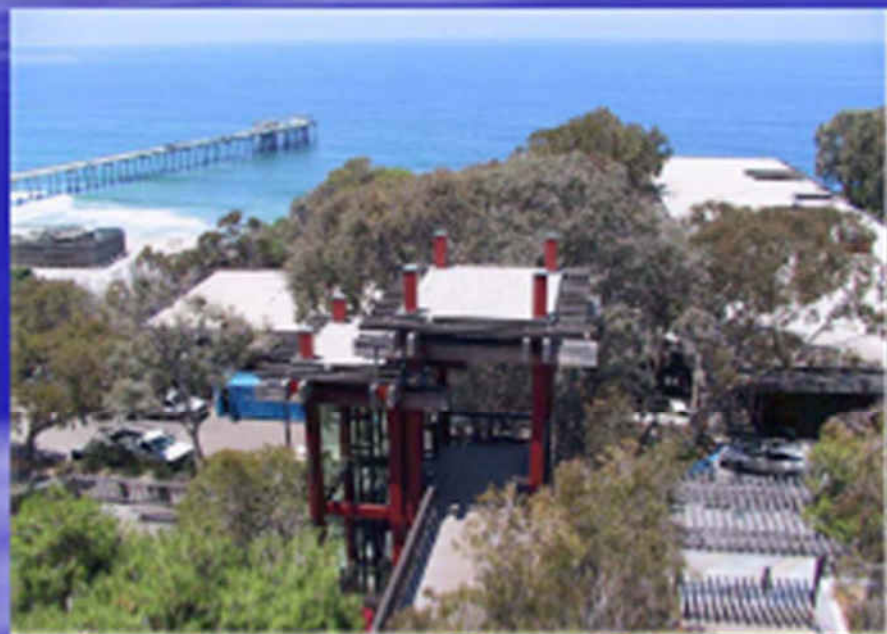
Paradox solved!

Investigators realized that life in the ocean and the physical, chemical and biological processes that control it are fundamentally different from that on land

Marine Biological Lab established in 1888 in Woods Hole, MA on Cape Cod

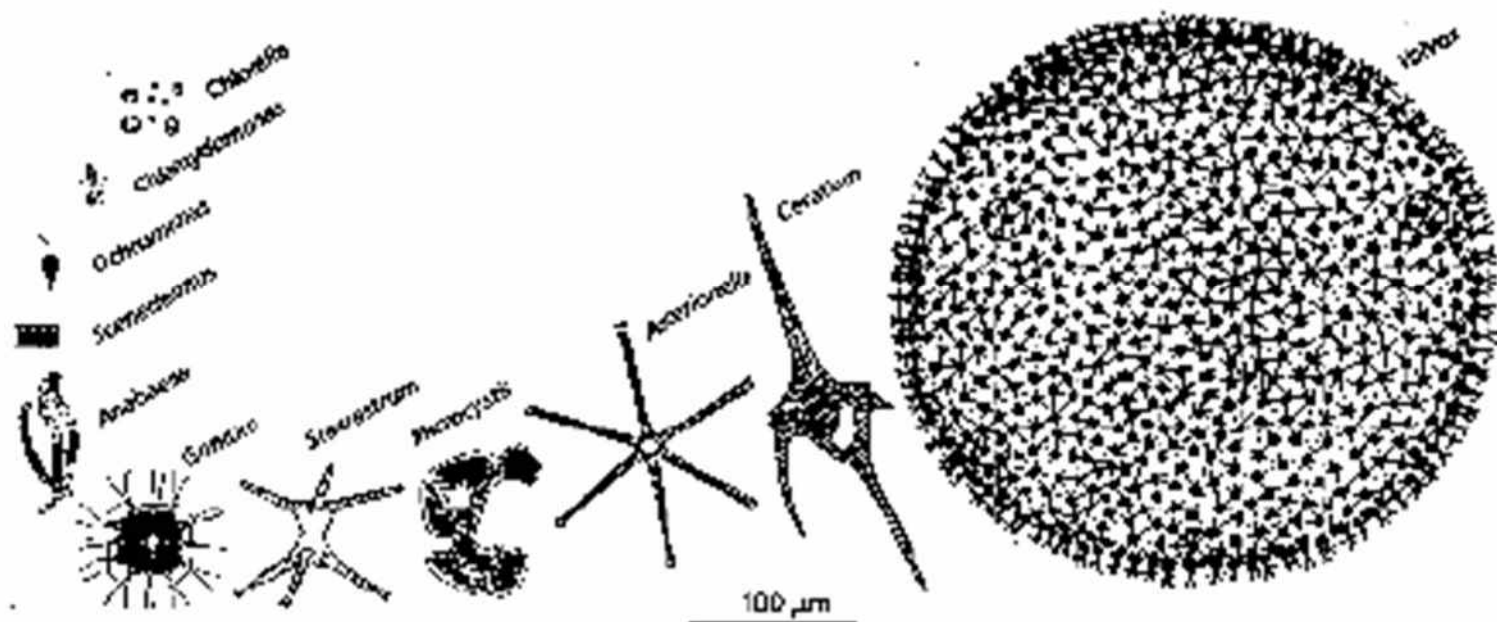


1903 Scripps Institution of Oceanography established (now and in 1910) in LaJolla CA



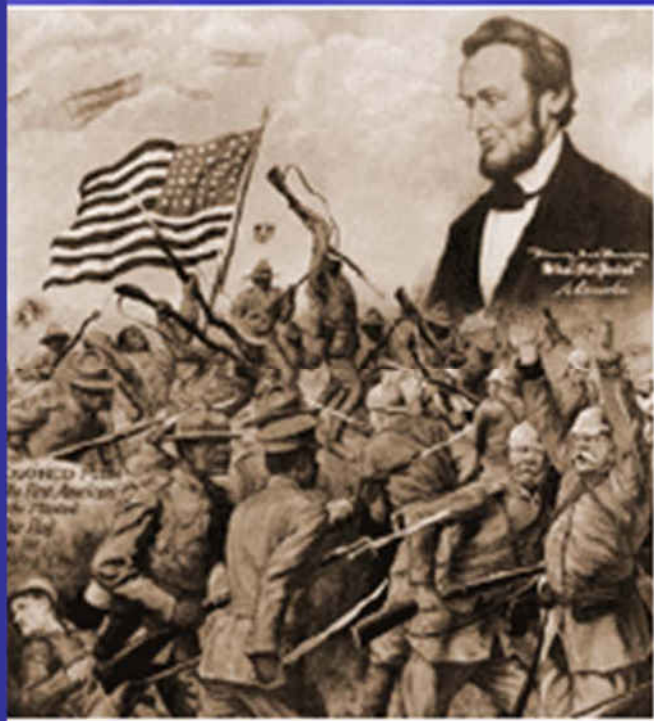
1911:

Lohmann from Kiel argued that many phytoplankters go right through the meshes of plankton nets. He called them nanoplankton and found the cells in the guts of appendicularians. He speculated that they could be important food sources in poorer seas. He said (in 1896) that 60-90% of all plankton goes through the net meshes. **Nobody listened to him.**



With the use of nets and limitations on the size of the meshes, it was becoming clearer and clearer that the bulk of the plankton were not the larger ones, but actually the smaller ones! However until the 1960s and 70s the technology wasn't available to adequately study the really small plankters that Lohman discovered.

A lot of plankton research
delayed by two world wars.



Claude Zobell 1st Marine Microbiologist at Scripps. Classical Microbiologist . Used classical culturing methods. Noted nearshore ca. 1000 bacteria/ml but offshore only 100. Postulated that bacteria in the sea all came from land and they were getting diluted offshore. Later he realized that he was just culturing ca 0.1% of the bacteria and you can't use classical culture methods to estimate abundance of marine bacteria.

1942 "The Oceans" is published by Sverdrup, Johnson & Fleming. Provided a foundation for study of the sea



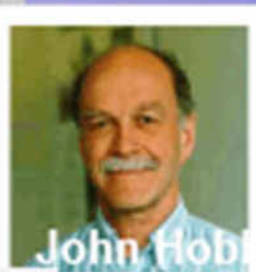
1950s: Primary Production

Gordon Riley and Steemann Nielsen controversy. O_2 vs ^{14}C . S-N said Riley overestimated PP in sea. ■

Late 1960's to '70's:

“Bacteria of little importance in ocean” theory proved incorrect by **John Hobbie & Richard Wright** with the development of the acridine orange method with ^{14}C labeled glucose to show activity. The bacteria were very active!

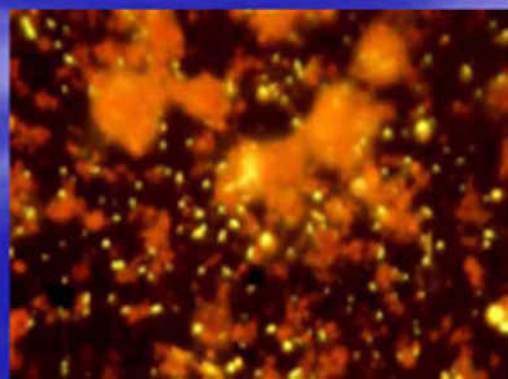
Gordon Riley



John Hobbie



Richard Wright

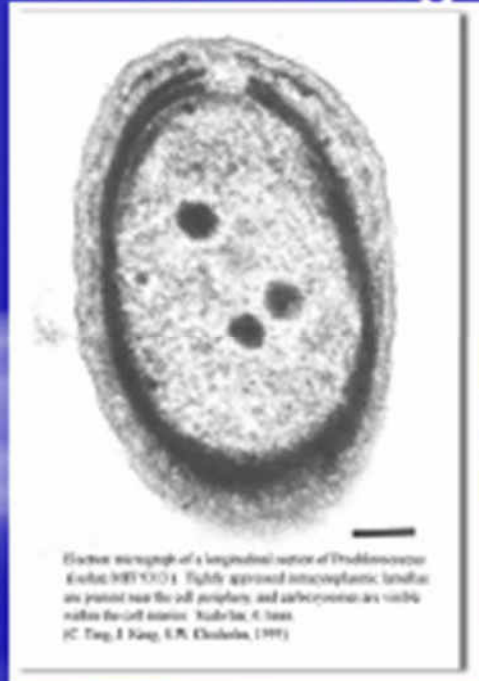


More Progress

- 1957-58 International Geophysical Year
- 1959-65 International Indian Ocean Expedition
- 1966 Congress establishes Sea Grant to provide funding for education & research in marine sciences
- 1970 NOAA established
- 1970s International Decade of Ocean Exploration
- 1978 Seasat-A, first Oceanographic satellite launched
- 1992 NASA launches TOPEX/Poseidon to monitor sea level & currents

Discovery of very high abundance of coccoid cyanobacteria, responsible for C fixation. 1980s-90s

Synechococcus & Prochlorococcus. The smallest phytoplankters are the most important. Lohmann was right!



Synechococcus



A after Prescott (1951)

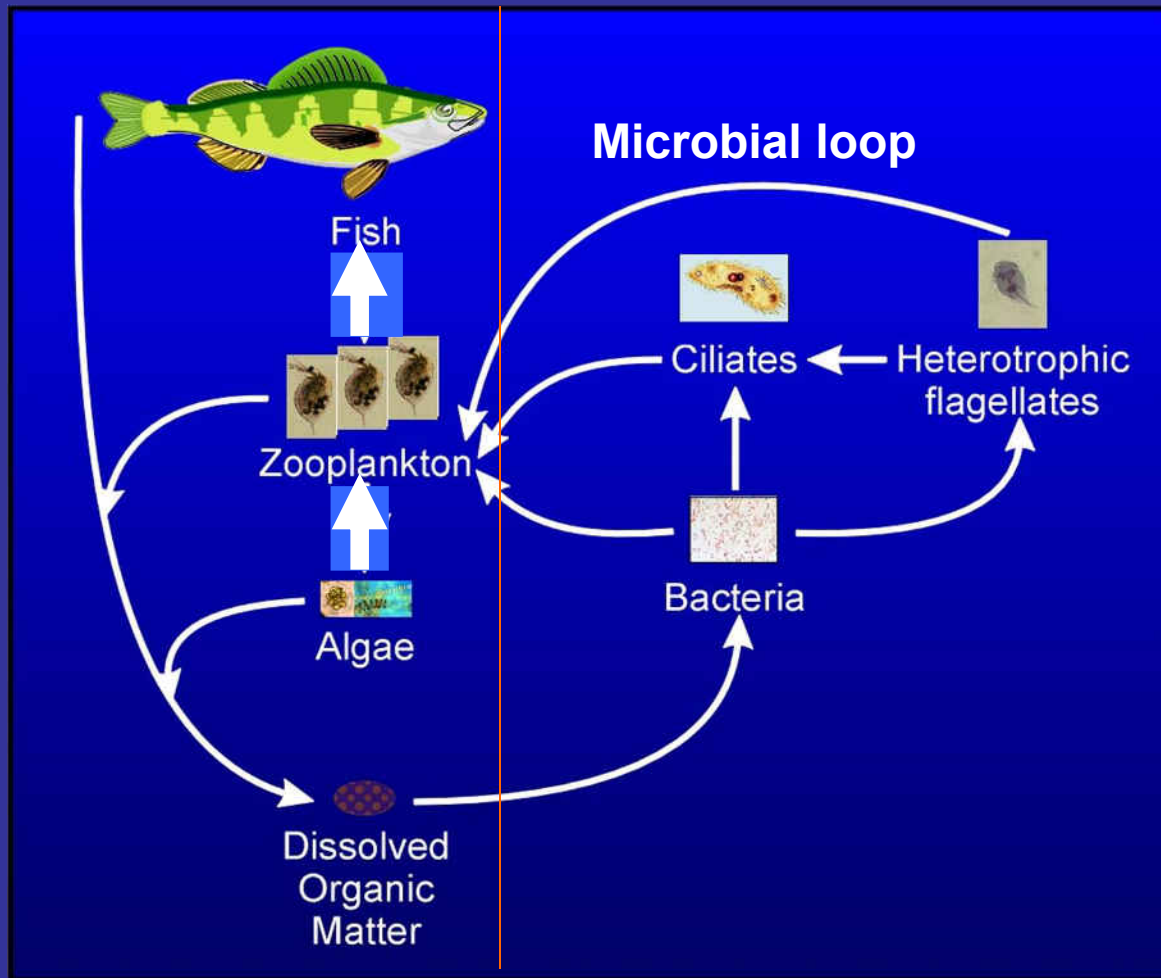
B © J. Ouyadomari, see http://www.bio.mtu.edu/~jkoyadom/algae_webpage/HOME.htm



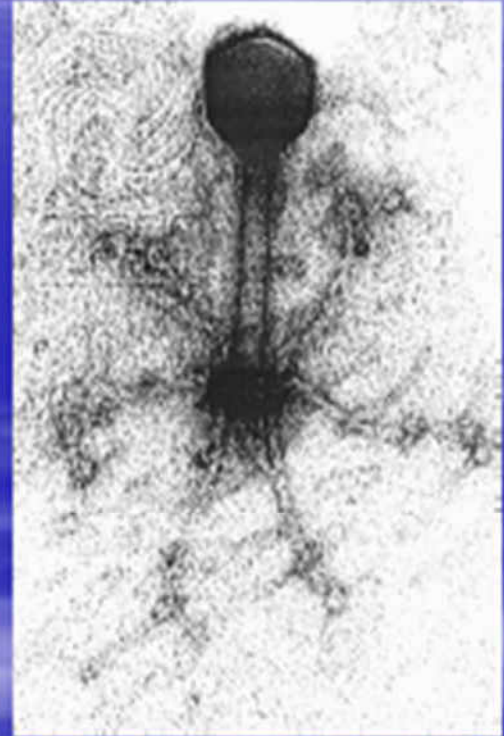
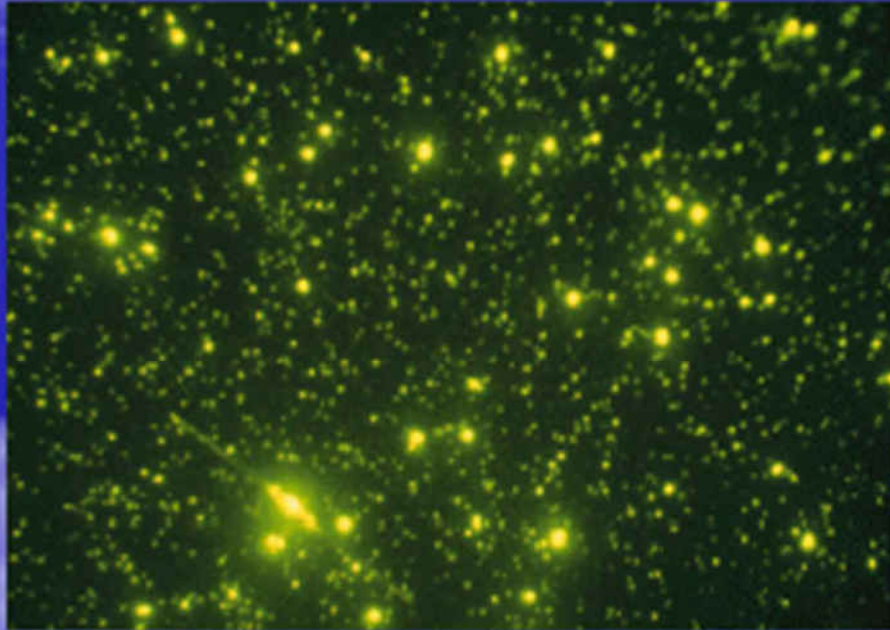
Importance of “**clean techniques**” for running productivity assays and for measuring trace metals. Surgically clean! Pioneered by John Martin & co-workers



Next, the concept of “**Microbial Loop**” by Pomeroy, Azam & Fuhrmans showed that bacteria could be very important in carbon fixation. >>Heterotrophic grazers.



1990's: Bergh et al., also
Proctor & Fuhrman
Importance of **viruses** in the
sea.



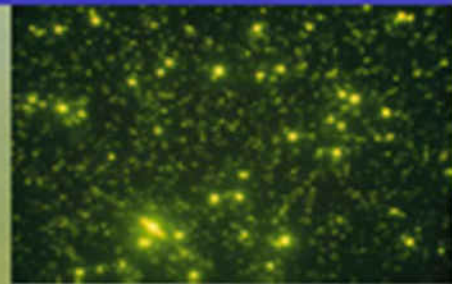
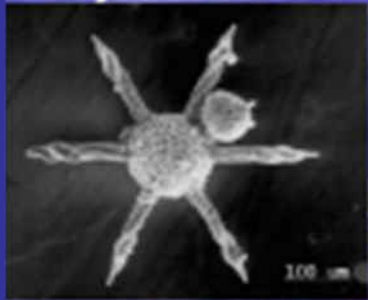


Today...

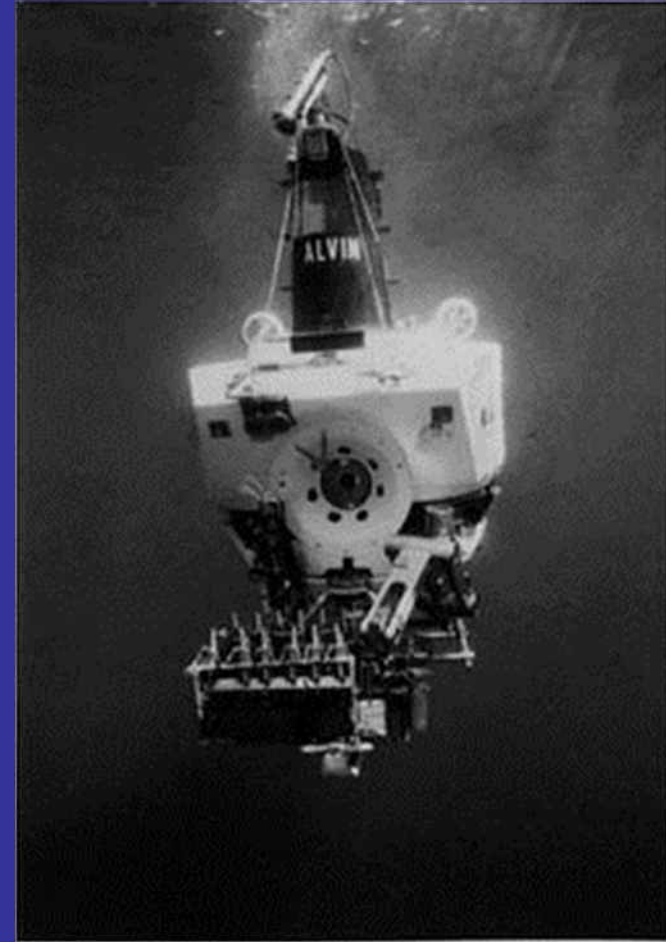
- Ships and sampling gear much more sophisticated. Scientists used to get water temperatures from reversing thermometers and water bottles put on the hydrographic line individually.
- Today, continuous readouts of salinity, temperature, light, O_2 , and chl *a* with depth. We can sample at selected depths.



A lot of discoveries and advances over the years have come from improvements in microscopes. Better optics in light microscopes, epifluorescence microscopy, stains. Fluorescent antibodies. EM, Flow cytometers, molecular biological developments.



- **Deep sea submersibles**
- **ROVs**
- **SCUBA**
- **Side scan radar, laser scanning**
- **Satellites**
 - **Sea surface gravity anomalies**
 - **SSTs/ENSO activity**
 - **Sea surface currents**
 - **Satellite imagery, GPS**
- **DNA replication/cloning/fingerprinting**





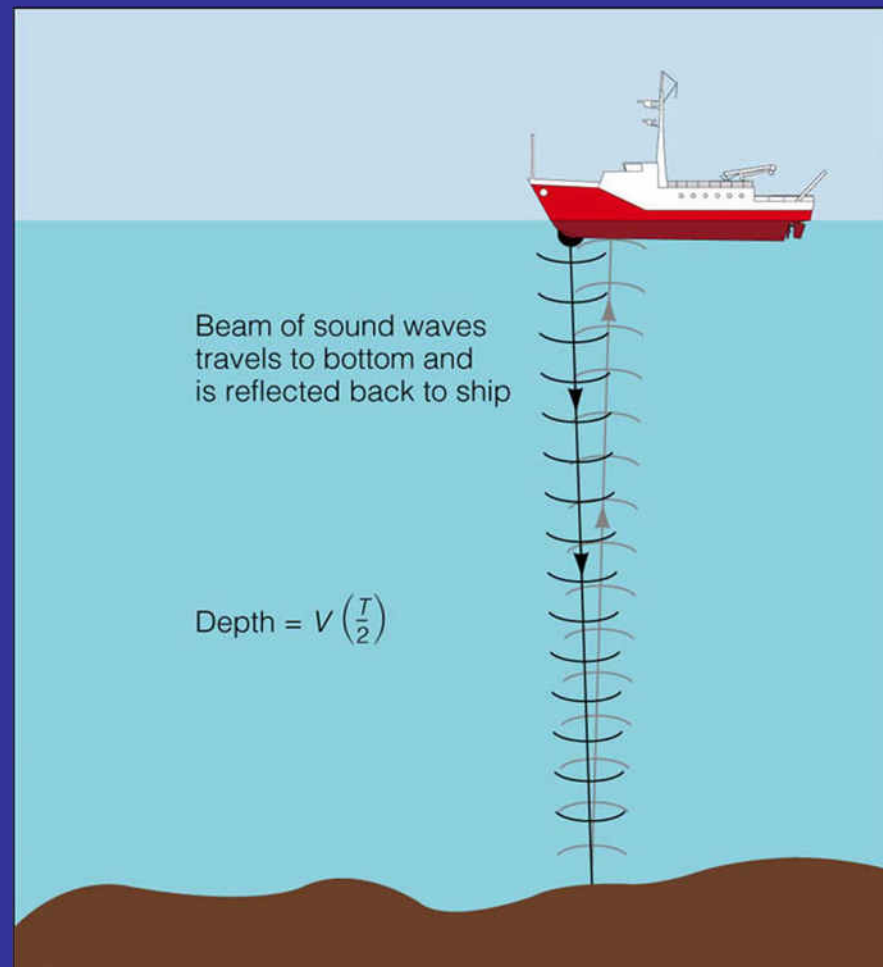
ROV



Shinkai 6500 – manned submersible



SCUBA



History of Biological Oceanography

Indian scenario

Marine Science in Universities

In Madras university marine biological research started in 1927 (Prof. R. Gopal Ayyar)

University of Travancore (now Kerala University) – started courses in Marine Biology in 1938

At the same time Bombay university started teaching Marine Biology under the leadership of Prof. P.R.Awati, Royal Institute of Science

In the early 50s, Andhra University started oceanography courses

At the same time University of Kerala, Trivandrum started research in Marine Biology under the leadership of Prof. C.C. John

Subsequently, Cochin University of Science and Technology started courses in all areas of Marine Sciences

Annamalai University with UGC support was elevated to Advanced Centre for Marine Biology Research

In mid seventies Marine Science Division was started in Berhampur University

Then Calcutta University introduced Marine Science

In mid 80s Goa University started Marine Science course

In addition, several inland Universities such as Delhi University, JNU, Banarus Hindu University, IITs, IISc also started ocean related courses

Post Independence Period

- Concept 'food from the sea'
- Research on fish and fisheries
- CMFRI established in 1947
- Indian Navy established NPOL in Kochi on research on defense oriented problems

International Indian Ocean Expedition (IIOE)

- In 1960, Govt. of India constituted Indian National Committee on Oceanic Research (INCOR) under the Chairmanship of Dr. D.N. Wadia
- Major task was to coordinate the international programme in Oceanography called **International Indian Ocean Expedition (IIOE)**
- IIOE was co – sponsored by UNESCO and International Oceanographic Commission (IOC)

- **40 ships from 20 countries took part in IIOE (1959-1965)**

- **Four ships from India participated in the programme - *I.N.S. Kistna*, *R.V. Varuna*, *R.V. Conch* and *M. F. U Bangada***

- **Bulk of data came from *I.N.S. Kistna***

- **With the support of the UNESCO and IOC Indian Ocean Biological Centre was established (IOBC) in 1962 at Cochin**

- **First task was to sort 2000 zooplankton samples collected from Indian Ocean to various taxa**
- **Also to store and maintain the archives of the samples**
- **The task was successfully completed and 10 atlases published to summarise the distribution of plankton groups**

- After IIOE the Indian National Committee on Oceanographic Research recommended the establishment of **National Institute of Oceanography (NIO)** that initially started at New Delhi (1966), subsequently shifted to Goa
- NIO carries out research on all the areas of Oceanography and currently is the leading Oceanographic Institution in the Indian Ocean Region
- Greatest impact of Indian Oceanography came with the commissioning of the first Oceanographic Research Vessel of NIO ***R.V. Gaveshani***
- ***R.V. Gaveshani*** had conducted several hundred cruises in the Arabian Sea and Bay of Bengal

- In 1981, **Department of Ocean Development (DOD)** (now Ministry of Earth Sciences) was established under the direct charge of Prime Minister with the following objectives

- Promote speedy development of ocean sector
- Provide funds for the co-ordination and co-operation of various institutes
- As and when required, open new Institutes and support the existing ones

ICMAM : NIOT : INCOIS : NCAOR : CMLRE

1983 – *ORV Sagar Kanya* – Oceanographic studies

1984 – *FORV Sagar Sampada* – mainly for marine fisheries research

Expedition to Antarctica

- In 1981, under the leadership of S.Z. Qasim Indian Expedition landed in Antarctica on 9th January 1982.

Now NCAOR controls the Indian Antarctic program.

- **1st permanent station 1983 - Dakshin Gangotri**
- **2nd Permanent station – Maitry (1990)**
- **Additional research station - Bharathi**
- **33 expeditions completed as on Dec. 2013.**



MAITRI



BHARATHI

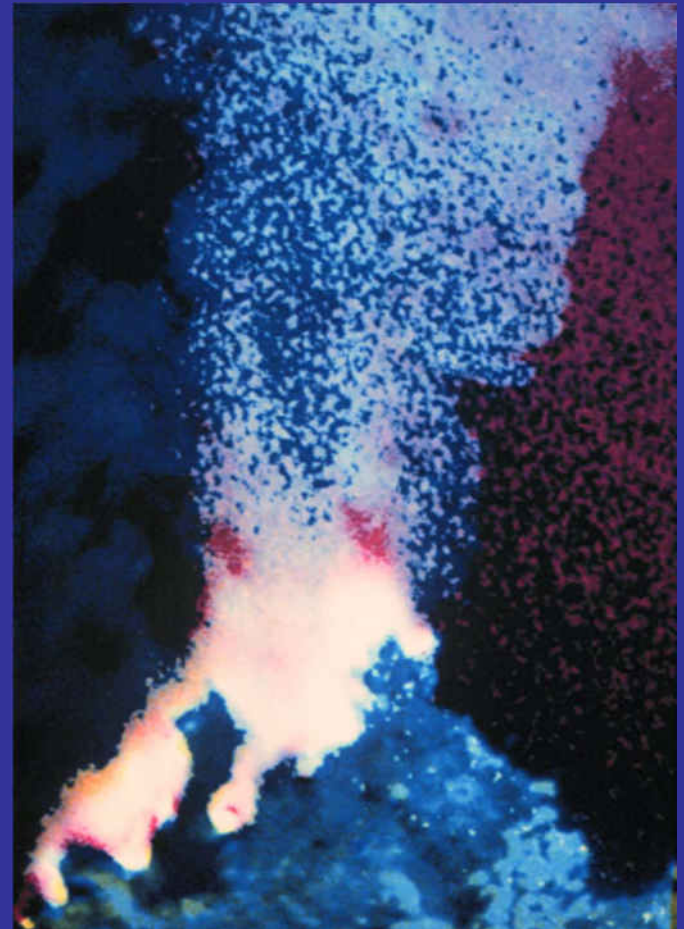


Frontiers in Ocean Discovery

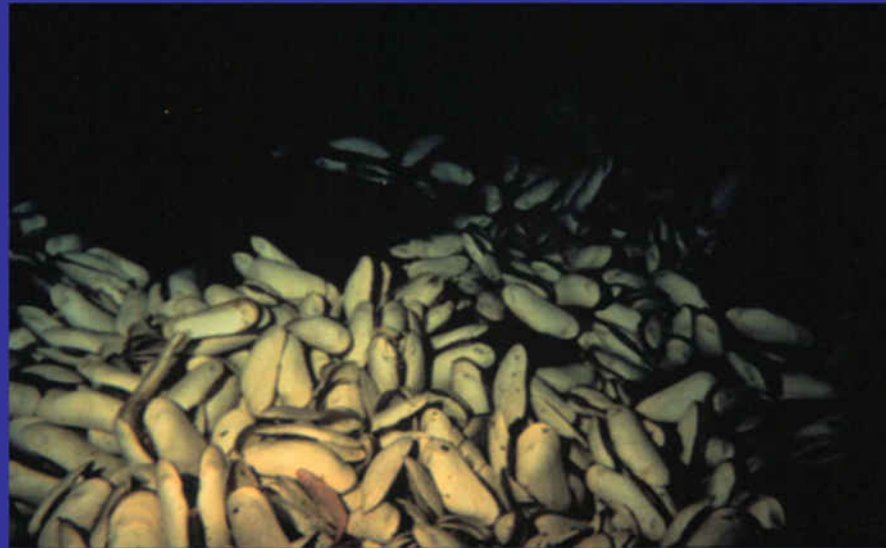
Hydrothermal Vents

Black Smokers

- Prior to 1977, biologists thought that without the energy of sunlight to support a food chain, organisms in the deep sea ate only what debris fell from surface waters. Scarce food meant that organisms were few and far between.



- After temperature-sensitive equipment returned small temperature changes at one site along the Rift (Galapagos), cameras were sent to the same site and returned with pictures of heaps of clam shells

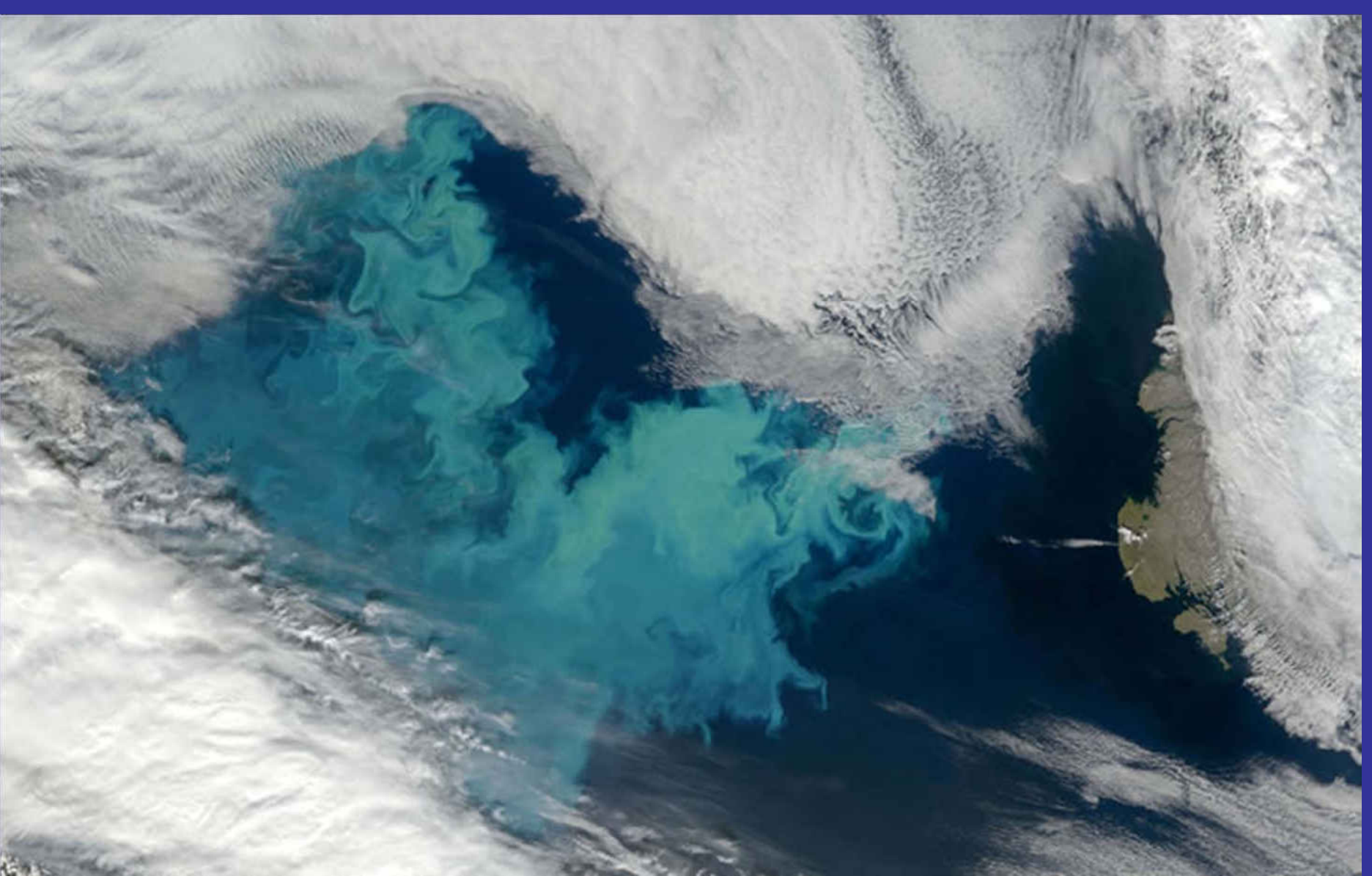


- Repeated submarine dives to the same site revealed temperatures as high as 46.4 degrees and a variety of unusual organisms

Remote Sensing is the acquisition
of physical data of an object
without touch or contact

Oceanic Parameters

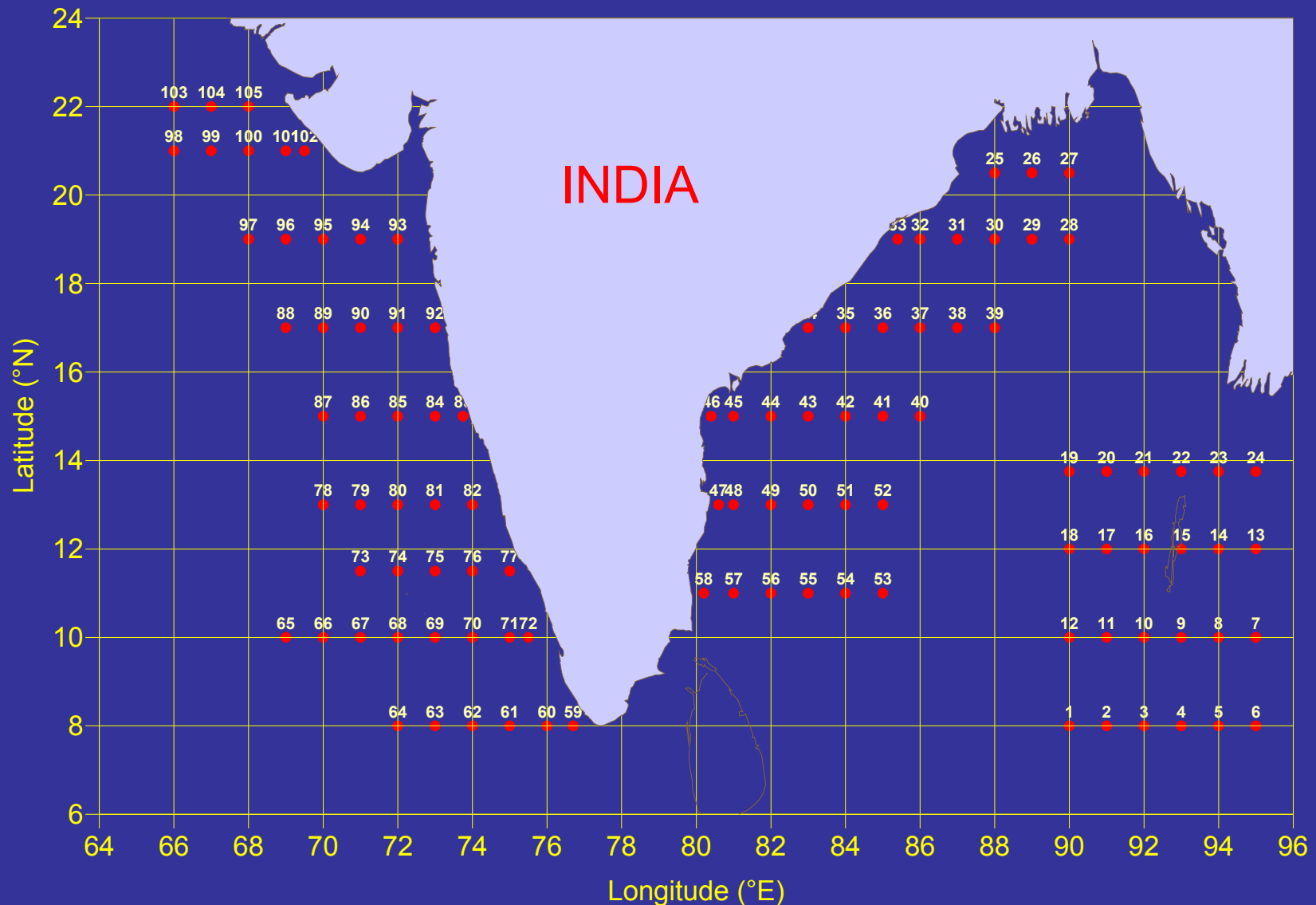
- Sea Surface Temperature
- Ocean Color
- Wind Speed and Direction
- Sea Surface Height – Currents
- Surface Waves, Height and Direction



Algal bloom in Barrent's sea

- IRS-P4 (OCEANSAT-1) has payloads, specifically tailored for the measurements of physical and biological oceanography parameters. An Ocean Color Monitor (OCM) with eight spectral bands, Multi-frequency Scanning Microwave Radiometer (MSMR) operating in four frequencies provide valuable Ocean-Surface related observation capability. The OCEANSAT-1 was launched by PSLV in early 1998.

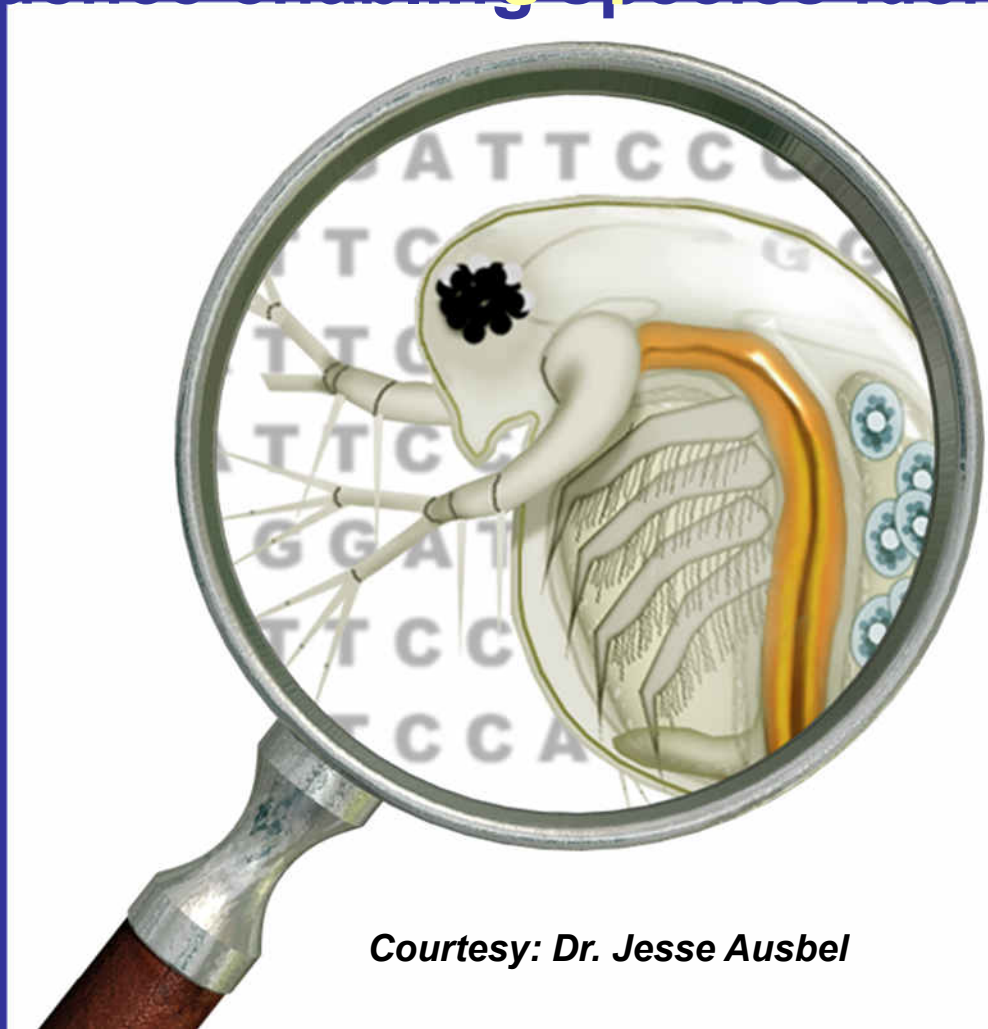
MRLR Station Positions



In 1998, Marine Living Resource Program (MLR Programme) was formulated by MoES with a view of promoting ocean development activities in the country which include mapping of the living resources, preparing inventory of commercially exploitable living marine resources, their optimum utilization through ecosystem management and R & D in basic sciences on Marine Living Resources & Ecology.

DNA Barcode:

short sequence enabling species identification



Courtesy: Dr. Jesse Ausbel

NIO's Biodiversity information products at NICMAS

- www.mangroveindia.org (MoEF)
- www.reefindia.org (MoEF)
- www.indian-ocean.org (DSIR)

- Prawns of India (DBT)
- Crabs of India (DBT)
- Mangroves of India (DBT)
- Fungi
- Corals (on CD)

Indian Ocean Biodiversity Information - IndOBIS

<http://www.indobis.org>



IndOBIS

Indian Ocean Node of OBIS

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Workshop on Biogeographic Information System for Indian Ocean *News!*

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