"You learn a lot by looking": The importance of exploratory observation (and occasional surprise) in biological oceanographic discovery

Calvin & Hobbes cartoon by Bill Watterson

Dave Mackas
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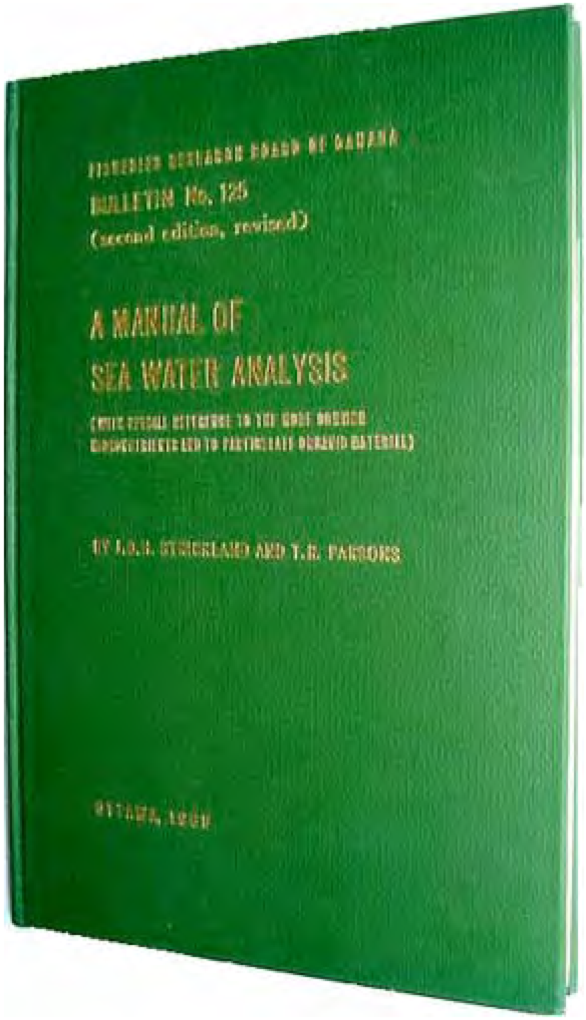
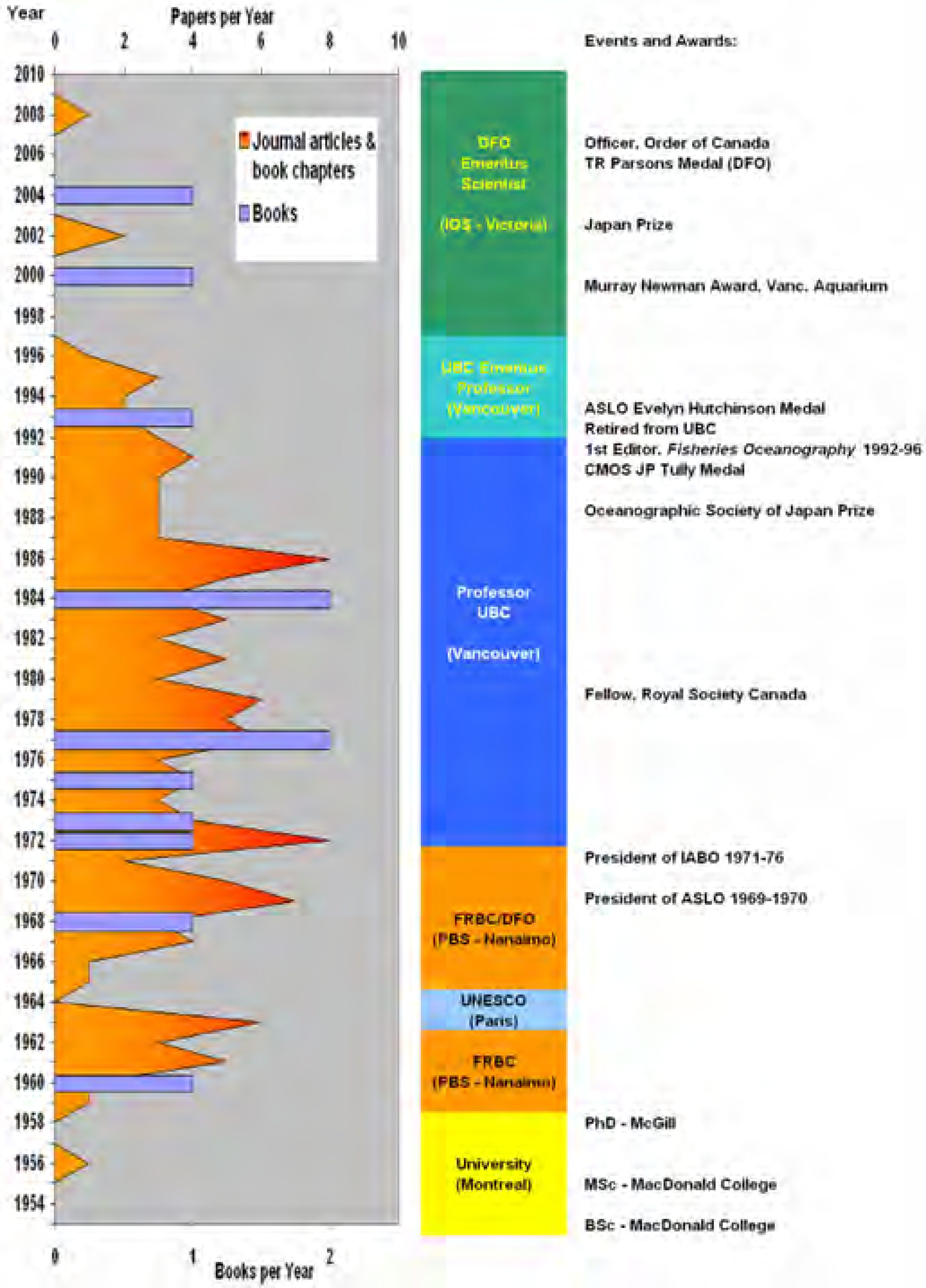
(but inspired by ideas from Parsons, Kuhn, Berra, Asimov, Feynman, Watterson….)

We're here today to celebrate the 50th anniversary of the first version of a VERY useful book (and also the career of its author: Timothy R. Parsons)





And quite a career it has been!

- >140 primary scientific papers
- 5 books (1st pair with multiple and distinct editions, 3-5 published post-retirement)
- 1 new journal (*Fisheries Oceanography*)
- Lots of medals and other awards

  and (not shown)
- Numerous book reviews
- 'Opinion Pieces' in both scientific and popular press

The Strickland & Parsons “Practical Handbook” is one of TRP’s earliest and most influential works

But my talk today is inspired by two later publications:

La mer 23: 109–110, 1985
Société franco-japonaise d'océanographie, Tokyo

Article spécial n° 3

Hypothesis testing and rigorous statistics as criteria for marine research proposals*

Timothy R. Parsons**

Oceanography is a young science, too young to become bureaucratised in its approach towards a better understanding of the world's oceans. In spite of this, there has recently crept into the minds of many funding agencies the need for scientists to define a testable hypothesis and to accompany applications for money with proposals which will yield statistically valid results. For the administrator, the submission of both a testable hypothesis and the proposed use of rigorous statistics gives the application a ring of scientific authenticity and veracity which can be readily defended to those who are concerned with the taxpayers' dollars. Unfortunately the approach may not yield *new* discoveries about the oceans.

I do not want to suggest the elimination of grant proposals which outline scientists' intentions. Rather my plea is to assure that researchers may probe the ocean depths without necessarily having to formulate their plans into some preconceived idea (the hypothesis) of what they expect to find. While fisheries data are collected for many purposes, it has perhaps been their endless use in order to verify the hypothesis of a "maximum sustainable yield" that has been one of the most oversold chronic forms of hypothesis testing (Larkin, 1977). It has resulted in very little being known about long term changes in fish populations relative to the large amount of money expended. In contrast, I believe that the recent flurry of papers (e.g., Harbison *et al.*, 1978) on the massive occurrence of gelatinous zooplankton in the sea has been largely the result of developing a new way to look at the ocean (i.e., open ocean SCUBA diving). This was not the result of any testable hypothesis and it did not require rigorous statistics for verification. The importance of this discovery may in fact have far reaching effects on fisheries science since in many cases the "jellies" are competing for the same food resources as commercial fish. The description of populations of large deep sea fishes and scavengers (e.g., Isaacs and Schwartzlose, 1975) and the discovery of the hydrothermal vent communities (e.g., Edmond, 1982) are additional recent examples of hitherto unknown phenomena.

Many theoreticians and administrators in marine science have long abandoned the essential element of field observations. What we really need to know about fish populations is

* Received March 2, 1985
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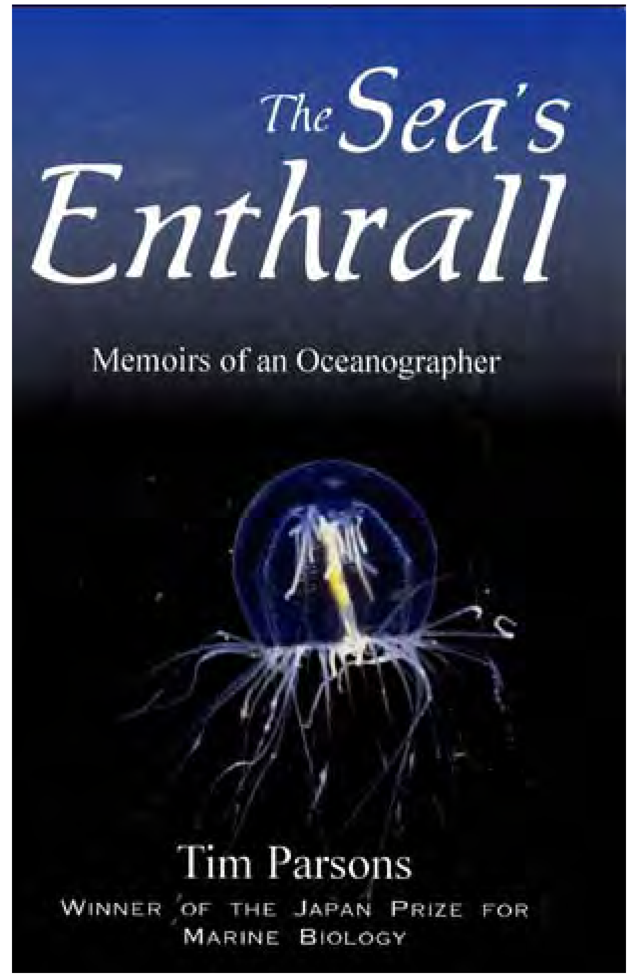
1985, in *La Mer*



2004 book

Some TRP quotes (slightly shortened):

(From Parsons 1985):

- "Oceanography is too young to become bureaucratized in its approach towards better understanding of the world's oceans"
- "My plea is [to let] researchers probe the ocean without having to formulate some preconceived hypothesis of what they expect to find."
- "…Recent flurries of papers [on gelatinous zooplankton, large deep sea fishes, hydrothermal vent communities] have been largely the result of developing new ways to look at the ocean…"

(From Parsons 2004 pp 95-96):

- "In 1970, Kuhn rebutted Popper, claiming that [large scientific advances] come about as the result of astute observation of the unexpected, and not from incremental hypothesis testing"
- "Nature can lead us into extraordinary insights, many of which might not be included in a prior hypothesis, because they were unknown when the grant application was filed."
- "I like to go into a general area (marine ecosystems), see what I can find out, and be ready to change direction "with the wind"."

These views about scientific progress and opportunity are not unique (but are especially valid in ocean science)

"What's the opposite of 'Eureka!'?"

'Unanticipated novelty, the new discovery, can emerge only to the extent that the scientist's views about nature and his instruments prove wrong' – Thomas Kuhn

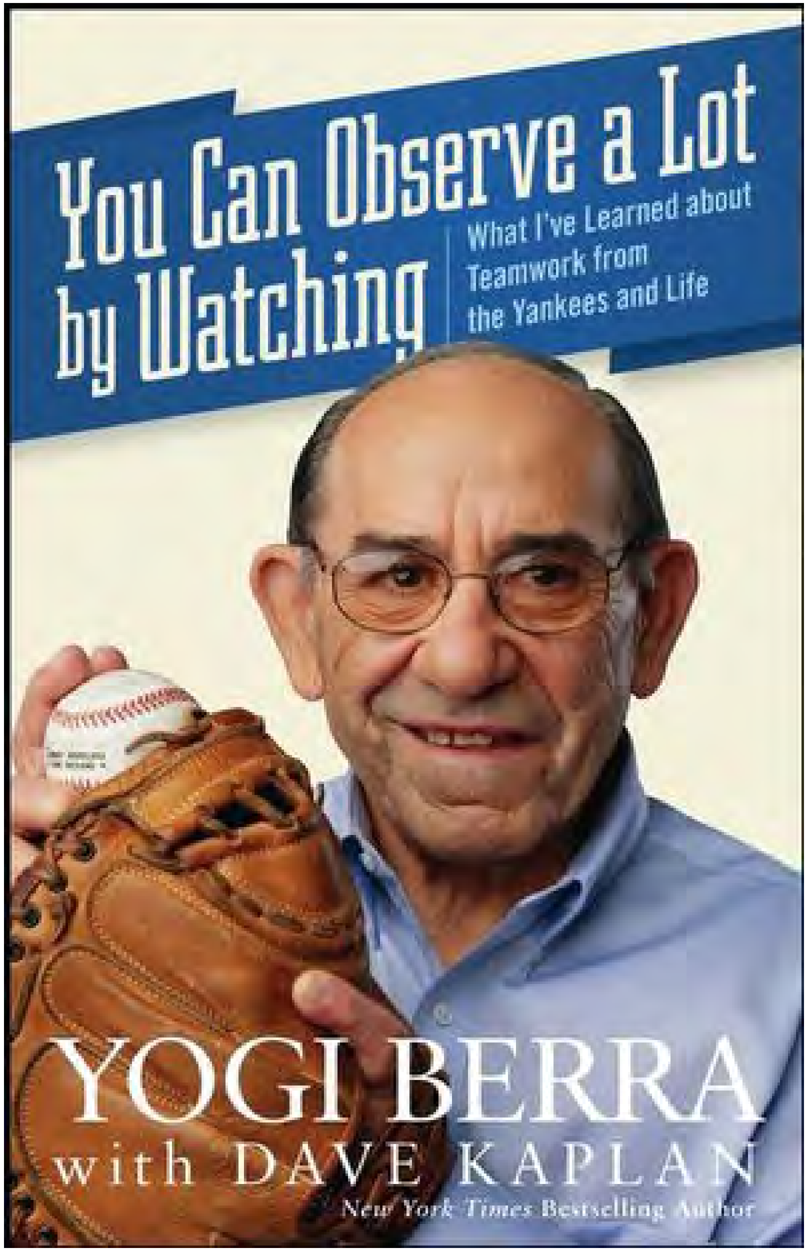
'The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!', but 'That's funny…' -Isaac Asimov

'The thing that doesn't fit is the thing that is most interesting' – Richard Feynman

quotes & cartoons from:
Parsons 2004 and from
http://bytesizebio.net/index.php/tag/science/

Neither are they unique to science or scientists

But (unlike me), Tim was always more inspired by tennis than by baseball



A formal 'hypothesis test' ☺ of how and why Tim developed a preference for discovery over experiment

H_O : He had never learned how to design experiments

- (REJECTED, $p \ll 0.05$): Strong experimental track record, e.g. publications from grad school, lake enrichment studies, and the CEPEX/Marine Mesocosms program

H_{A1}: His NSERC research proposal was not funded

- (POSSIBLE, $p \sim 0.2$): Most good scientists have an ego, but very few hold a grudge for 20+ years.

H_{A2}: He had experienced 'observational surprises' in ocean science, and was often delighted by both the process and the scientific outcomes

- (ACCEPTED, $p > 0.75$): Examples to follow

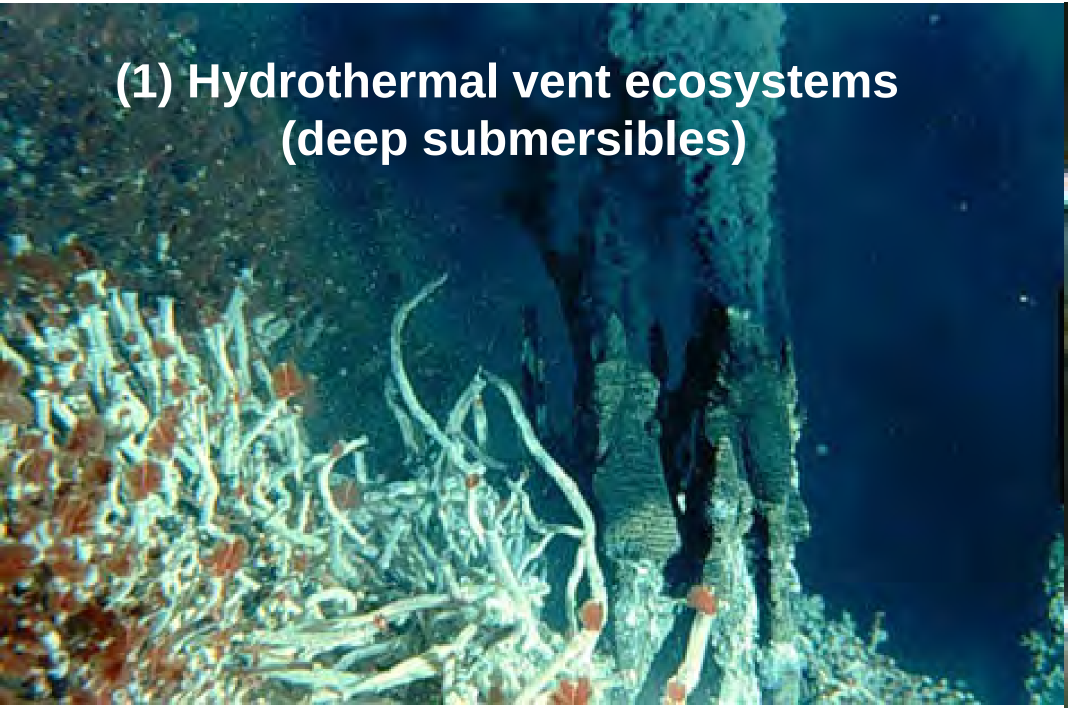
How can “observational surprises” arise?? (At least 4 potential paths)

Japanese Garden- Portland. GO!!

1) By looking in ‘new’ places (but running out of these?)
2) By looking with new methods that can ‘see’ patterns or objects that were previously invisible
3) By merging diverse ~synoptic data (usually obtained by multiple methods) into multilayered ‘maps’ that reveal linked pattern.
4) By reanalyzing historical data sets in new ways.

- Note: important attributes of what can be done (and how) have evolved rapidly in the last decade

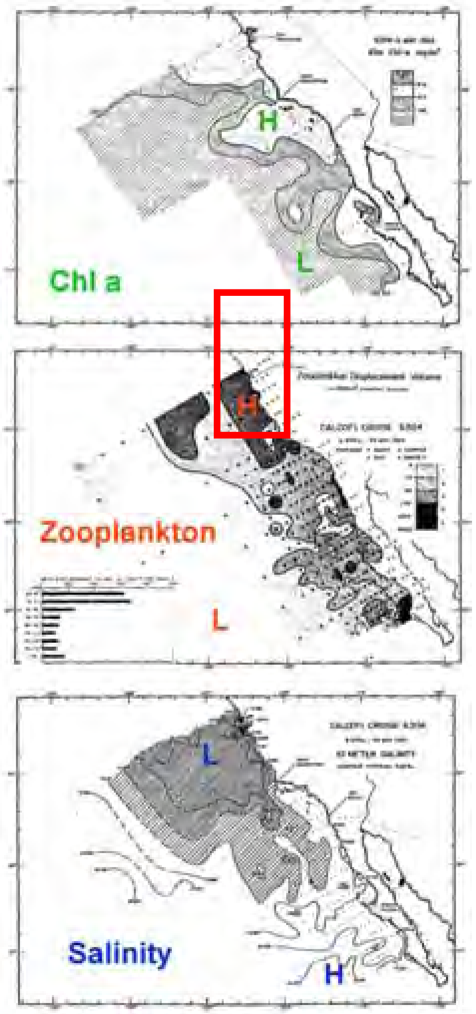
Tim's (1985) list of surprise oceanic discoveries: (Paths 1& 2: new observing methods,new places)



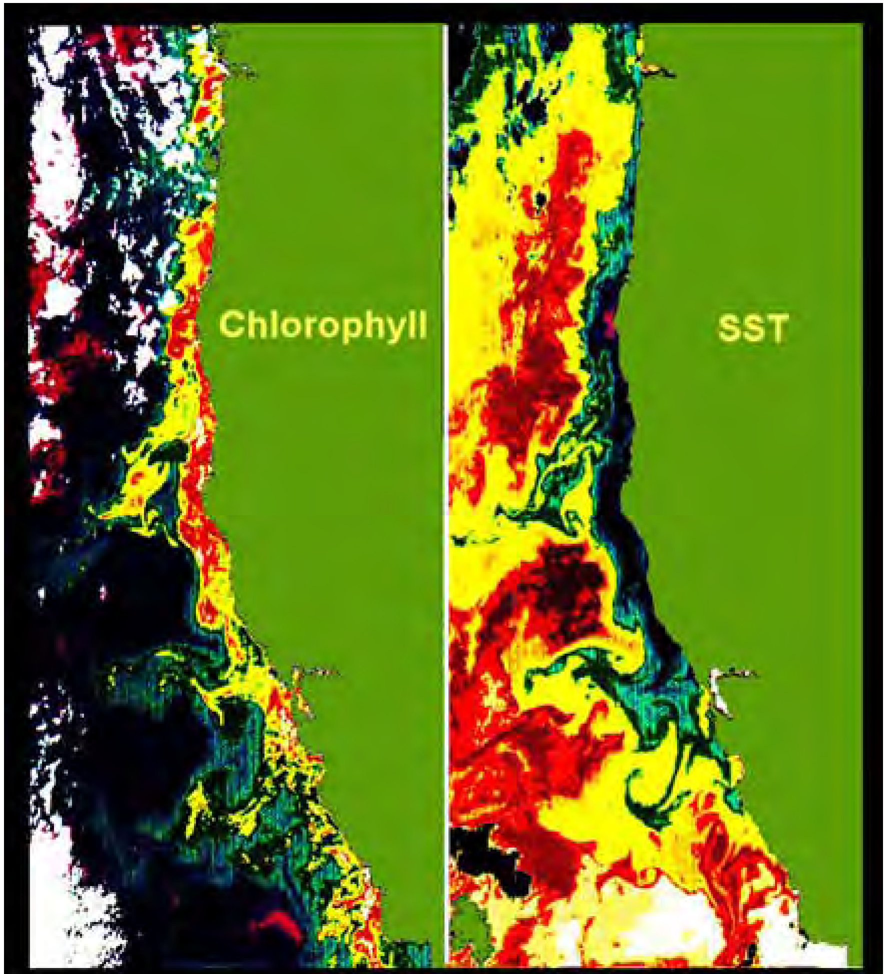
3) Abundance and ID of large deep-sea fishes (baited 'monster' cameras, e.g. Isaacs and Schwartzlose 1975)

Photo credits:
Vent fauna – U.Victoria - Tunnicliffe & Franklin
Diver & jelly – UCSB web site – Alice Alldredge

A slightly newer 'Path 2' example (late 1980s): Intense mesoscale 'squirts & jets' in the California Current are revealed/resolved by satellite imagery



Bernal 1981

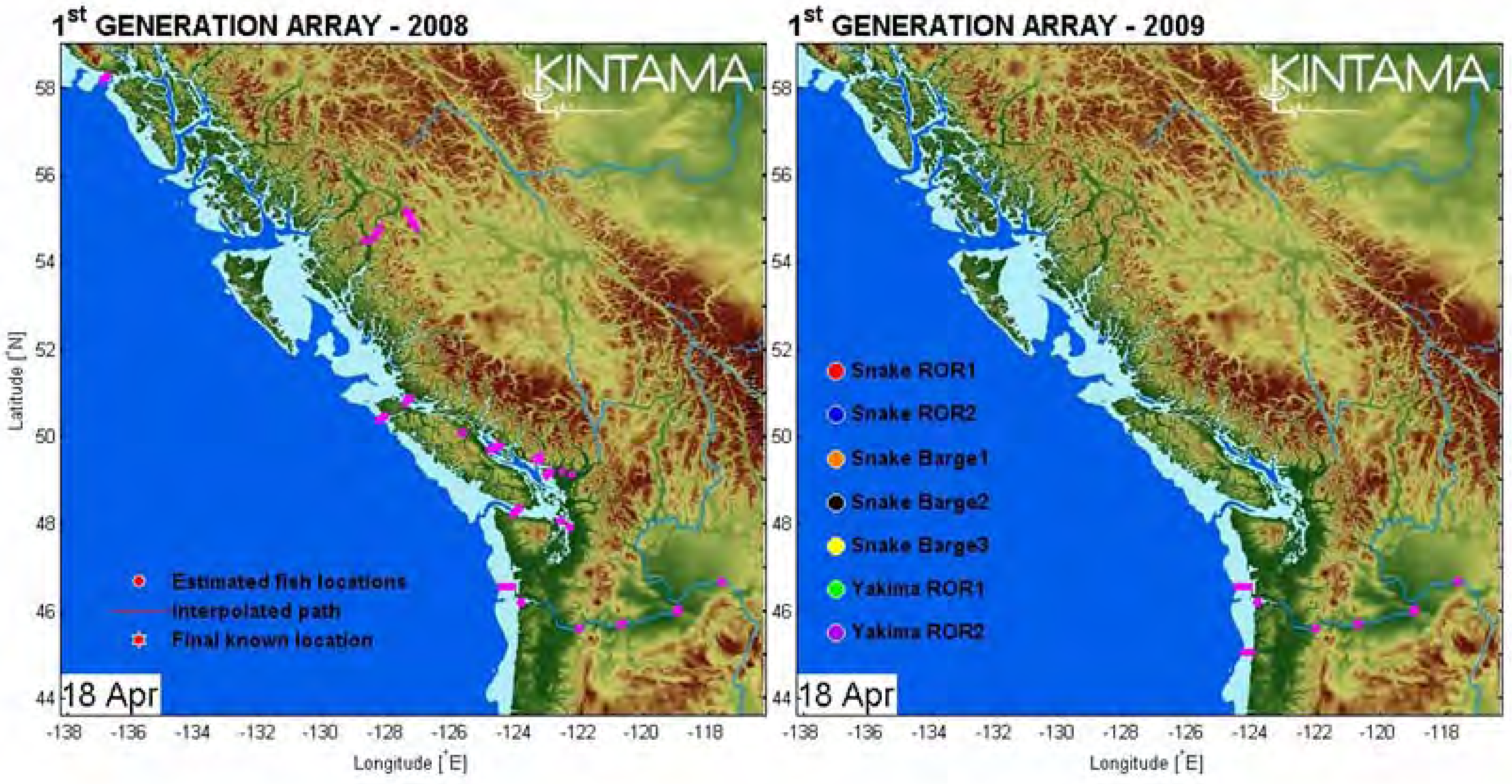


(from Brink & Cowles 1991)

Some recent 'Path 2' examples of new observation methods

(a) Acoustic tags + listening arrays can localize 'Where' & 'When' for key biological events and processes

(for more info see http://www.postcoml.org/ and Welch S15-6650)



Juvenile salmon migration: animation & data courtesy D. Welch

(b) Structural & functional genomics reveal "Who is doing What & When"

- DNA or RNA amplification & sequencing can be applied to individual organisms
- Can identify not only what genes are present (taxonomy) but also **what genes are active** (developmental status, condition, stress, disease)

For more info: J. Nielsen (FIS-P-6567) & S. Johnson et al. (FIS-P-6847)

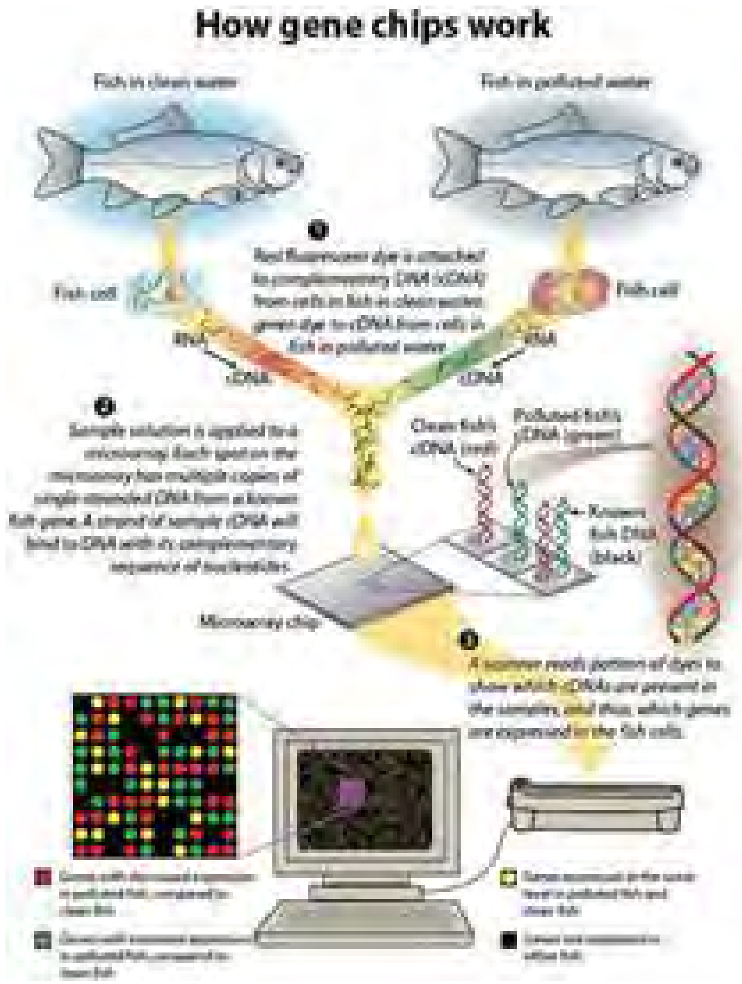
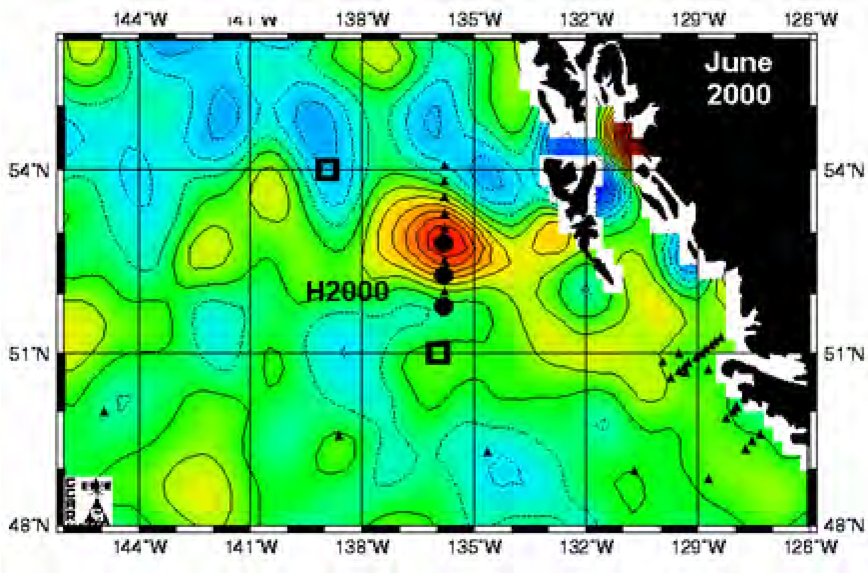


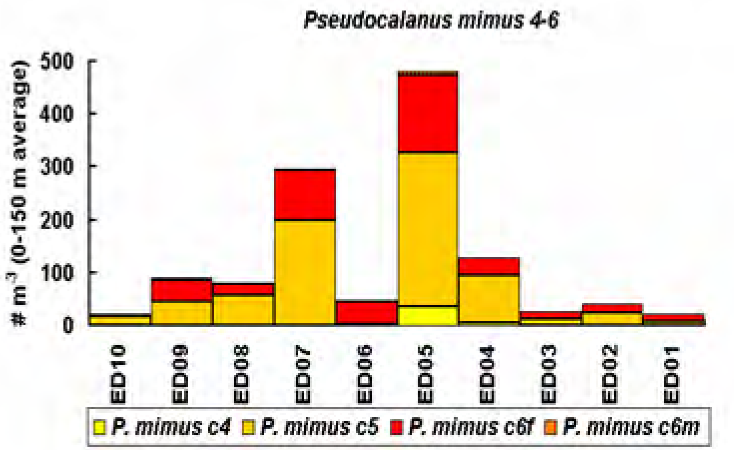
Figure (courtesy Jack Cook WHOI) from Hahn 2005

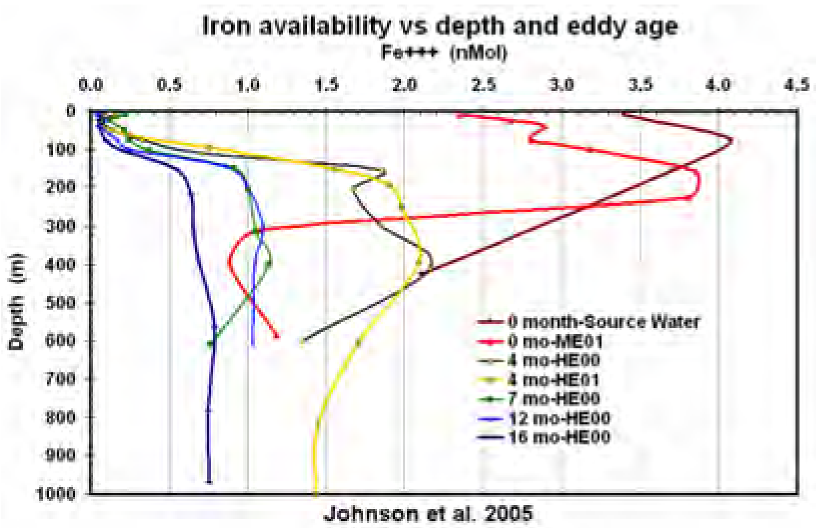
Path 3 to surprise discovery: Layer data from multiple sampling methods into 'maps' that show shared pattern.

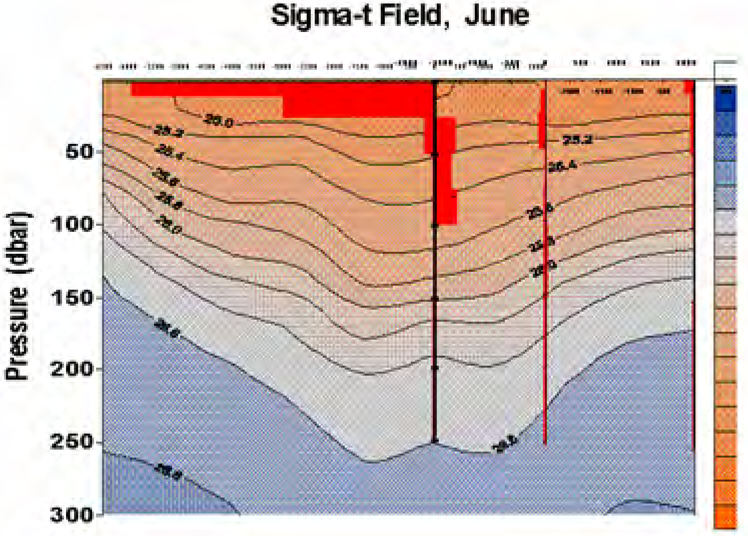
- Oceangraphers have always done this, but
- New sampling methods now offer new combinations
- New computers & software now allow bigger combinations and much better visualizations of shared patterns
- Individuals and/or small teams can now make large and diverse compilations

Combining diverse data types – (a) Coastal-origin eddies in the oceanic Subarctic Pacific (located by satellite altimeter, then sampled by ships)



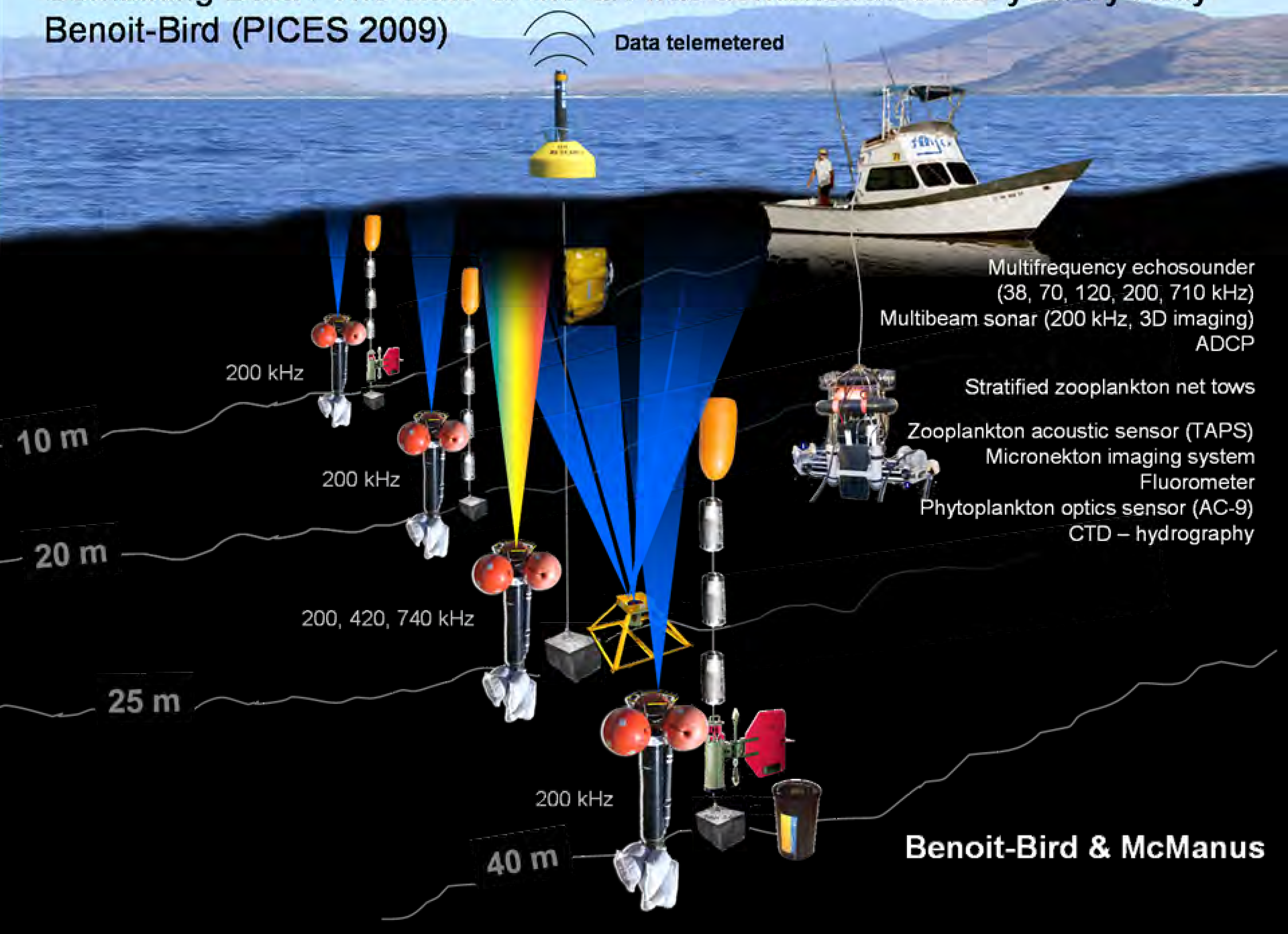




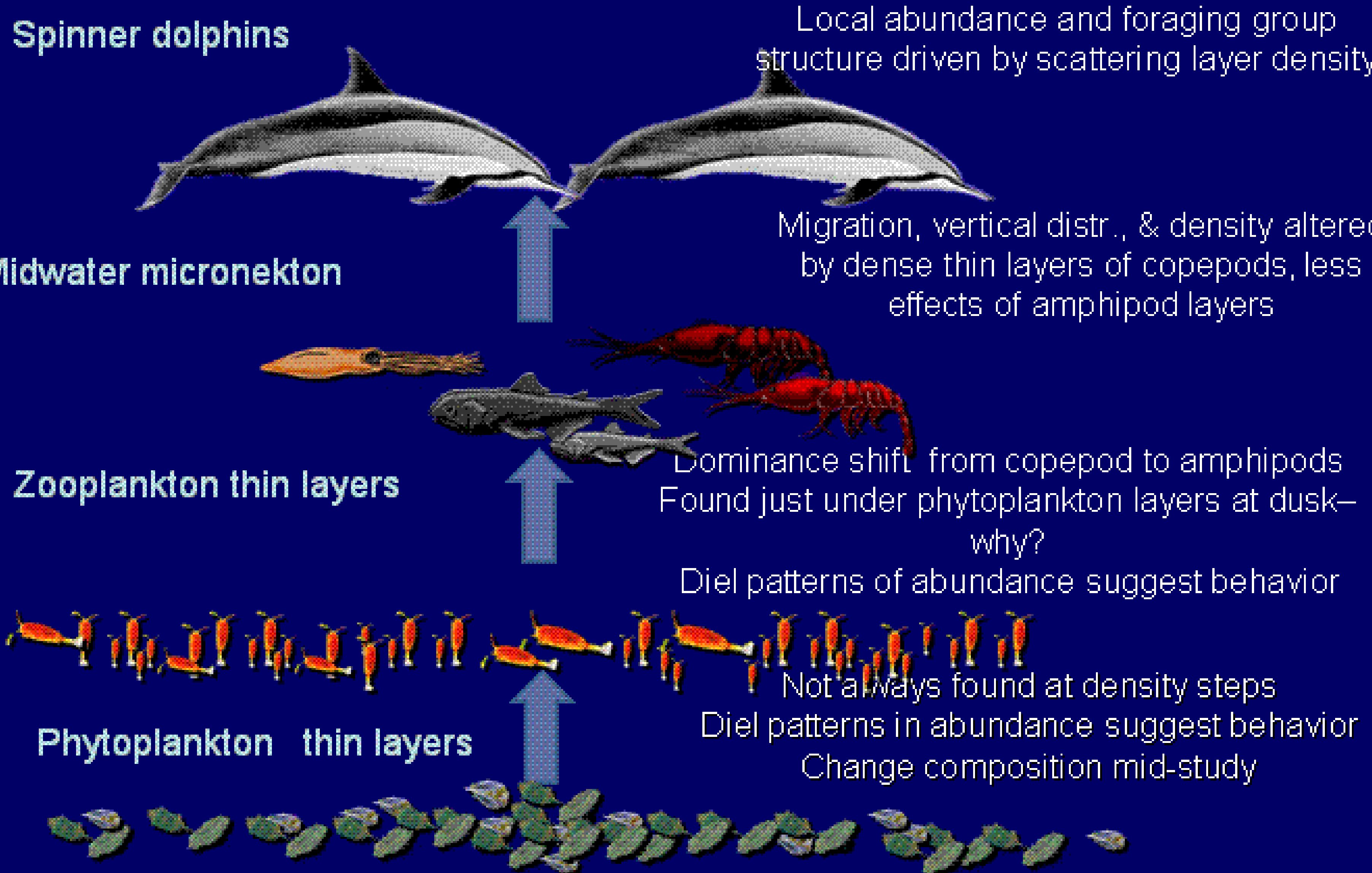


from Mackas & Galbraith 2002

Combining Data : The state-of-the-art was demonstrated last year by Kelly Benoit-Bird (PICES 2009)



System driven from the bottom up

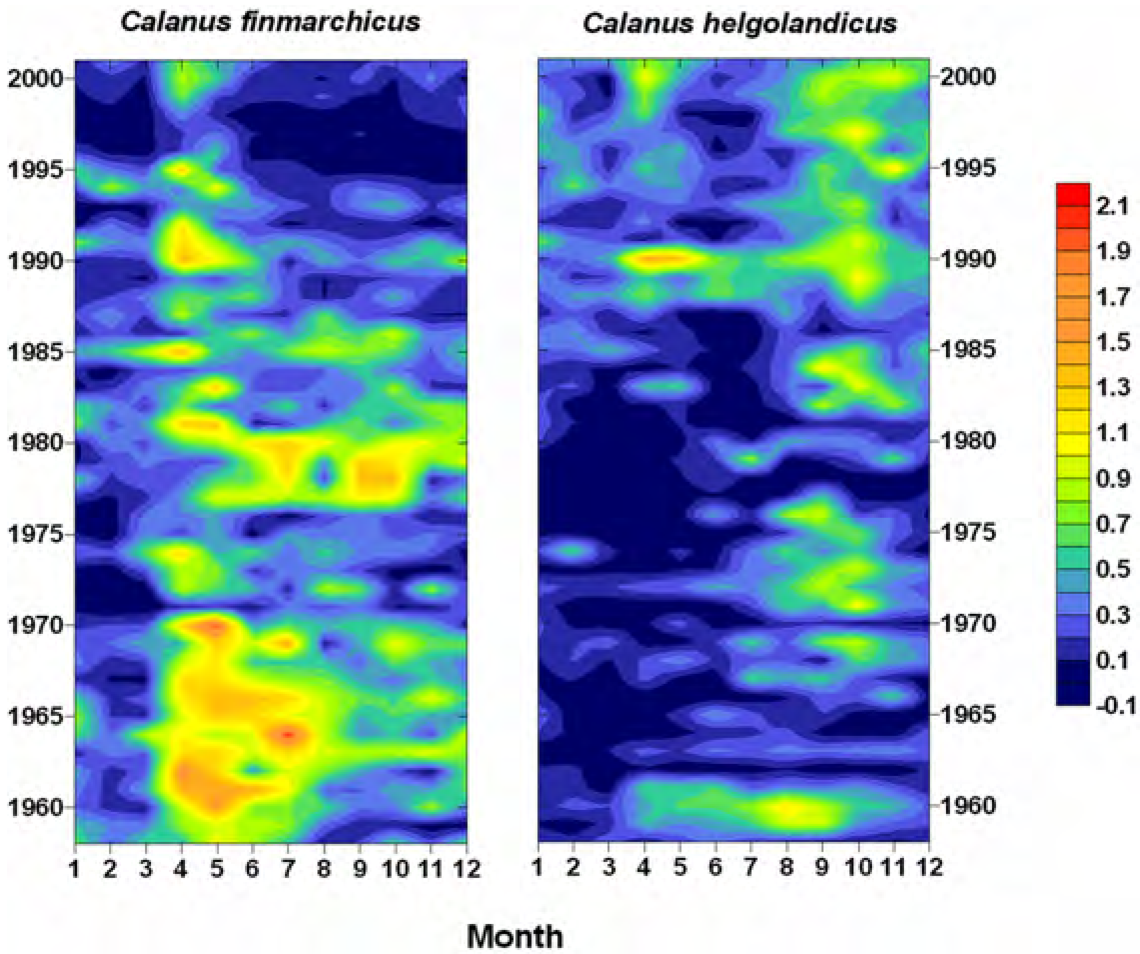


Benoit-Bird & McManus

Path 4 to surprise discovery: Examine old data in new ways

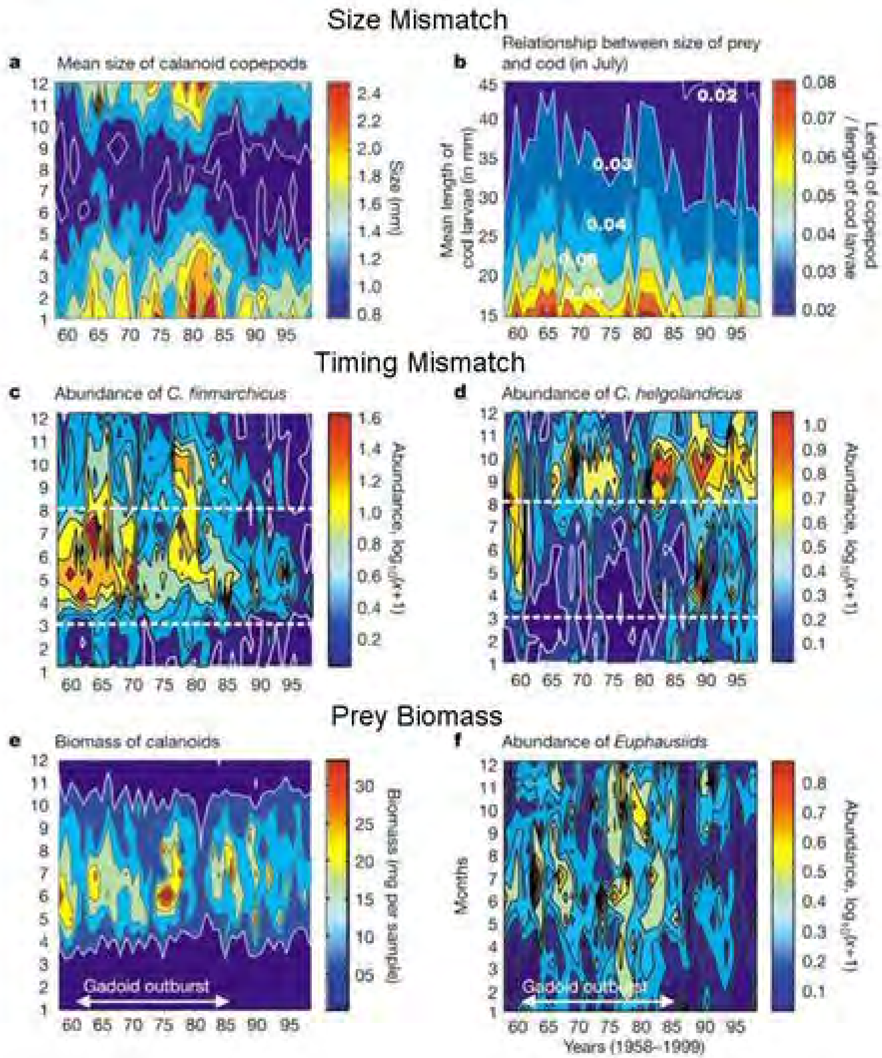
- Again, a long tradition, BUT
- The ocean is changing - new patterns and different variables are emerging as 'important'
- Dual challenges:
  - Access and verify useful data from the past
  - Anticipate what kinds of observations will be useful in the future

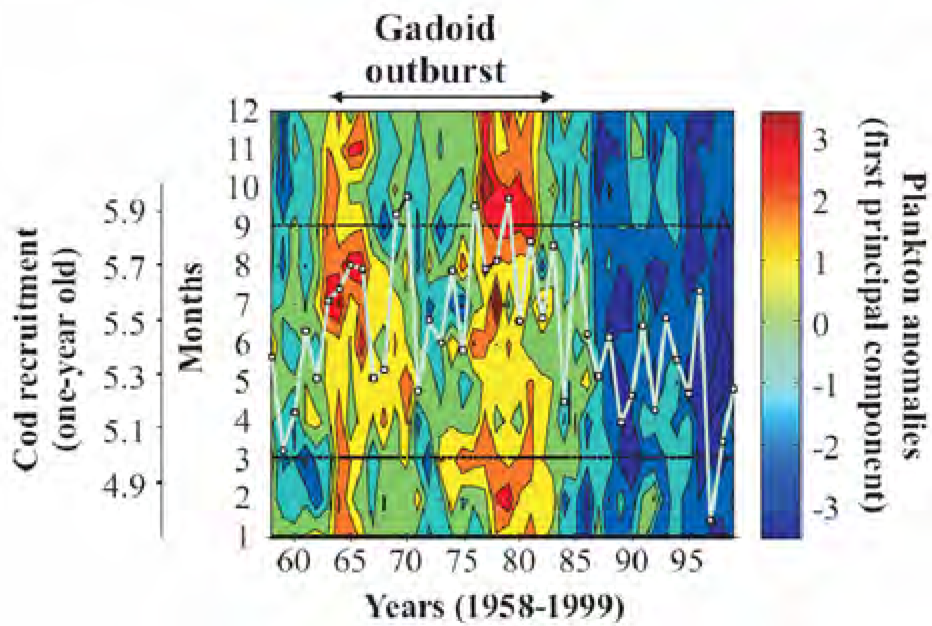
A prime example of old data viewed in new ways: CPR data shows North Sea replacement of *Calanus finmarchicus* by *C. helgolandicus*:



Spatial average log abundance (from WinCPR)

Calanus trends are coincident with several other big changes in the North Sea ecosystem:





Beaugrand 2003

‘Change’ will poses challenges for data archaeology:

Changing natural world:

- New state variables emerging,
- Different ranges for old familiar variables

Changing scientific capacity and sociology:

- Massive increases in data volume & diversity
- New archival and search mechanisms
- Decoupling of data collection from data use (who speaks today for the client of the future?)
- Econometrics & bioinformatics may offer better how-to models than meteorology?

In summary:

Many surprise treasures still to be found, BUT the search will be faster and more productive if you have:

1) One or more sharp new shovels
2) Map (new or old) suggesting where to look and how deep
3) For data archaeology, a translation guide (metadata) to help read what you dig up