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

Calvin & Hobbes cartoon by Bill Watterson

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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:

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)

‘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

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, \( p<0.05 \)): 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)

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

Japanese Garden- Portland. GO!!
3) Abundance and ID of large deep-sea fishes (baited ‘monster’ cameras, e.g. Isaacs and Schwartzlose 1975)

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

(1) Hydrothermal vent ecosystems (deep submersibles)

(2) Distribution & ecology of large, fragile jellies (blue water diving & submersibles)

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.

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

Multifrequency echosounder (38, 70, 120, 200, 710 kHz)
Multibeam sonar (200 kHz, 3D imaging)
ADCP
Stratified zooplankton net tows
Zooplankton acoustic sensor (TAPS)
Micronekton imaging system
Fluorometer
Phytoplankton optics sensor (AC-9)
CTD – hydrography

Benoit-Bird & McManus
System driven from the bottom up

Spinner dolphins

Local abundance and foraging group structure driven by scattering layer density

Midwater micronekton

Migration, vertical distr., & density altered by dense thin layers of copepods, less effects of amphipod layers

Zooplankton thin layers

Dominance shift from copepod to amphipods
Found just under phytoplankton layers at dusk—why?
Diel patterns of abundance suggest behavior

Phytoplankton thin layers

Not always found at density steps
Diel patterns in abundance suggest behavior
Change composition mid-study

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