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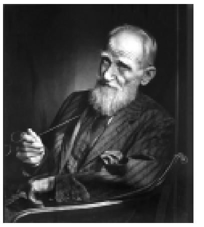

Etymology of Ghoti

George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.

On 'variability' as a sampling artefact: the case of *Sardinella* in north-western Africa

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Abstract

Objective evaluation of the global impact of fisheries on ocean ecosystems may be hampered by various biases suggesting natural variability of exploited species to be stronger and more widespread than is really the case. One of these is reporting biases: papers are usually not published which show that nothing has changed. Another such bias is that much variability is fishery-induced, i.e. due to the truncation by fishing of the age composition of exploited populations. A third source of bias, emphasized here, is that resulting from sampling a migrating population with a fixed device. This bias is illustrated by contrasting the relatively stable echo-acoustic estimates of biomass of *Sardinella* spp. along the north-west African coast, i.e. from Morocco and Mauritania to Senegal (data from 1992–98), with the more variable estimates of biomass in the waters of each of these countries. We conclude that published reports of 'variability' in exploited species should explicitly account for the effect of migrations and other movements, especially when such reports are to be used for contrasting fisheries-induced with environmental impacts on biomass.

Keywords population fluctuations, homeostasis, sampling variability, sediment cores, sardine

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Introduction

Fisheries, globally, are having an increasing impact on the biomass and age/size composition of fish and invertebrate populations (Pauly *et al*. 1998). However, the severity of this impact is still denied by some colleagues, usually with reference to the overwhelming role of environmentally induced 'variability'. The ensuing debate, spiked with frequent references to 'uncertainty', the sister buzz-word, can be used by managers as a justification for taking a business-as-usual approach. This is unfortunate, as some of the observed 'variability' is itself a result of fishing, which truncates age distributions, leaving the highly variable juveniles (or 'recruits') as major source of new biomass (Longhurst 1998), thus also adding 'uncertainty'.

One item frequently presented to illustrate the high variability of fish populations in the absence of fishing pressure are time series of fish scales in sediment cores (Soutar and Isaacs 1969, Shakleton 1988; Baumgartner *et al.* 1992), of which a much-cited example for the sardine (*Sardinops sagax*, Clupeidae) is given in Fig. 1.

However, inferring from scale abundances in a sediment core (or in several nearby cores, as in the case of Baumgartner *et al.* 1992) to the biomass of a population requires, among other things: (i) that the number of scales shed per biomass and time units is more or less constant; (ii) that sedimentation and fossilization rates are constant and proportional to scale deposition; and (iii) that the entire population is represented by the core, i.e. that the density of fish over the area sampled by the core, throughout the series, is representative of the biomass of the population.

Assumptions (i) and (ii) are parsimonious, and we accept them. We believe, however, that assumption (iii) is often not consistent with the inferences for which it is used, for biomasses vary in space, not only in time. Thus, while it is possible to sample a time series from a moving population with a stationary sampling device, inferring from the variability of the sample to that of the biomasses of the populations is not straightforward. If the sampling device happens to be located in 'optimal habitat' *sensu* MacCall (1990), then it will not reflect the successive range extension and collapses of the varying population. It will therefore suggest less biomass variability than really occurs. In the more likely case that the device is located in non-optimal habitat (more likely because optimal habitat will tend to be small, relative to overall habitat), the raw data from the device will tend to suggest more biomass variability than really occurs. Thus, in any case, the contribution of movements relative to the sampling device must be evaluated. The original authors of the series in Fig. 1 were well aware of this when they wrote:

> "Our analysis of the signal-to-noise ratio indicates a need for further sampling of the long time series to capture the complete range of variability of [biomass] over the basin ... this is particularly important ... to distinguish possible 'interactions' between spatial and temporal variability in [biomass] over the basin"

However, so far as we can tell, none of the many contributions citing the text of Baumgartner *et al.* (1992), and often reproducing the graph presented here as Fig. 1, mentions the potentially biasing effect of the small area represented by their core samples, given the wide geographic range of the North American stock of Pacific sardine, from the tip of Baja California to south-eastern Alaska (Parrish *et al.* 1989). We suggest that this is due to the reporting bias noted so far only by Ursin (1982) for fisheries and marine science, i.e. the tendency to publish on items (biomass levels, community structure, etc.) that have changed, but not on those that have remained the same. In medicine, on the other hand, authors of formal meta-analyses are admonished not only to cover the published literature, but also to include unpublished manuscripts and reports, in order to counter the bias on evaluating treatment effects that results from the observed tendency not to publish reports of ineffectual treatments in the primary literature (Hodges and Olkin 1985).

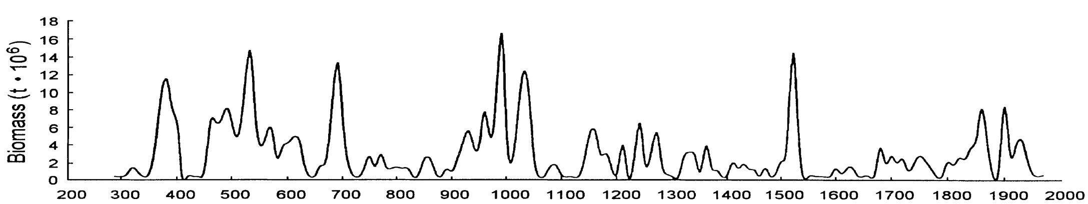

Figure 1 Time series of relative abundance of Sardine (*Sardinops sagax*) scales in a sediment core from the Santa Barbara Basin, California (from Baumgartner *et al.* 1992).

Case study: *Sardinella* biomass fluctuations off north-west Africa

In the absence of spatially explicit time series of biomass for the period represented by Fig. 1, we use here the admittedly short time series in Fig. 2 to illustrate a case where a fixed sampling device, even if large enough to cover the coast of a medium-size country from north to south, would overestimate the biomass variability of a migrating stock of small pelagics. These series represent acoustic estimates of the combined biomass of *Sardinella aurita* and *S. maderensis* (Clupeidae) off north-western Africa, two species closely related to the Pacific sardine (Parrish *et al.* 1989), and occurring in an Eastern Boundary Current system similar to that off California (Bakun 1996). Notably, *Sardinella* migrate seasonally up and down the north-western African coast (Garcia

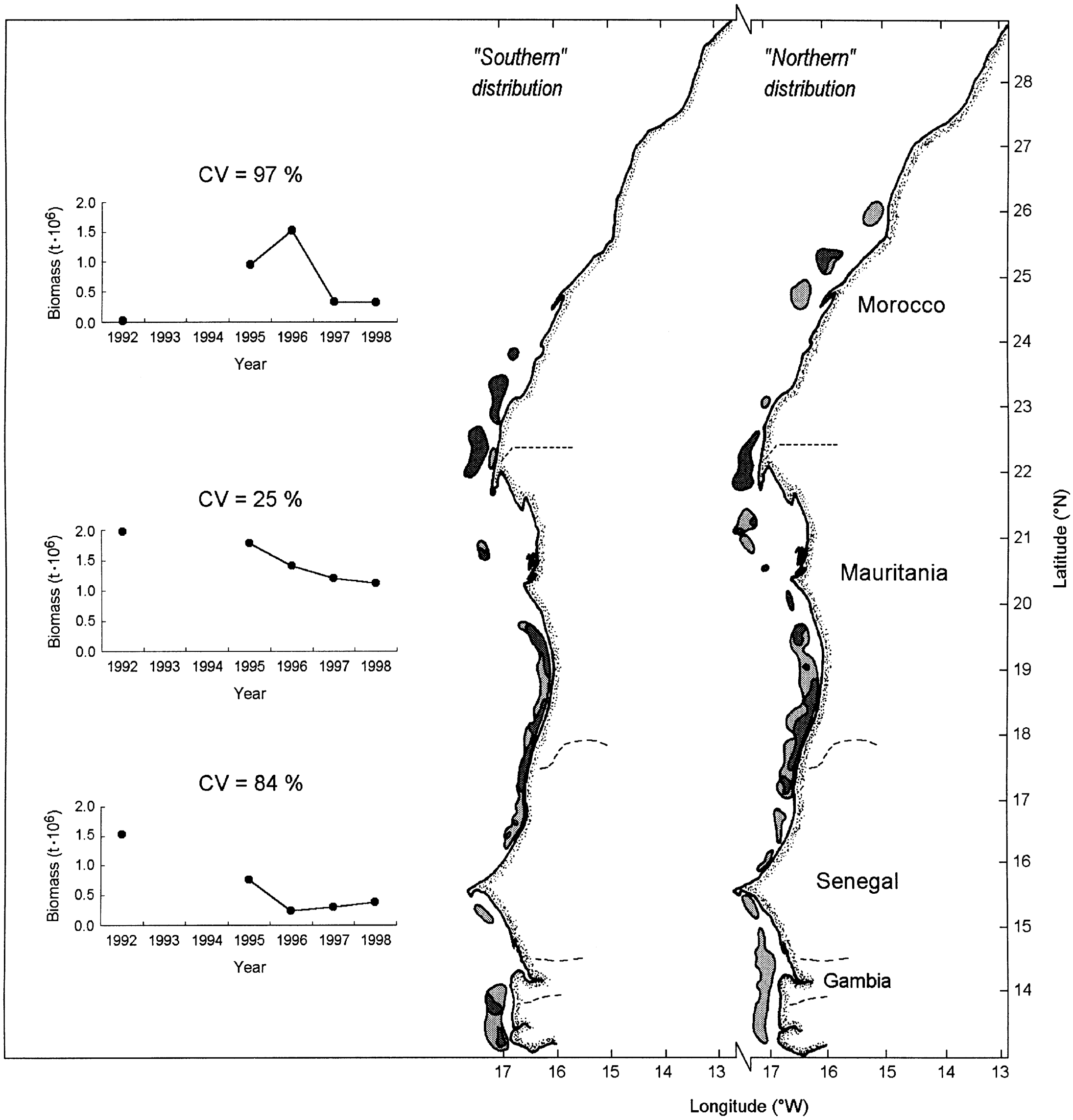

Figure 2 Migration of *Sardinella* spp. along the coast of north-west Africa, and time series of echo-acoustic estimates of biomasses along the coast of Morocco, Mauritania and Senegal (based on data in Anon. 1992–98 and FAO 1999). The percentage coefficients of variations (CV) were calculated from $CV = SD \times 100/x$, where x is the mean biomass from 1992 to 1998, and SD is the standard deviations of the annual biomass estimates from x. The graphs illustrate two years with strongly differing distributions: 1992, when the *Sardinella* stock tended to occur mainly in the south of its range ('southern distribution'), and 1996, the converse of this situation ('northern distribution').

1984), just as Pacific sardine migrate up and down the California coast, the amplitude of these migrations varying between years mainly as a function of the thermal regime (Pauly 1996).

Figure 2 shows that, as a result of these changes in the amplitude of these migrations, the biomass of *Sardinella* occurring in the waters off Morocco and off Senegal/Gambia (i.e., at the two ends of the populations' range) vary far more than off Mauritania. Indeed, the biomass off Mauritania, in the central part of the populations' distribution, is the only series with a trend corresponding to the overall biomass trend. Thus:

- the overall biomass of *Sardinella* from Morocco to Senegal/Gambia remained fairly constant (CV = 31%) from 1992 to 1998;
- the apparent variability of the biomass was much higher at the end of the range (off Morocco 97% and off Senegal 84%) than at the centre (off Mauritania 25%); and thus:
- a core sample of *Sardinella* scales extracted from the sediments off Morocco or Gambia (or indeed any national sampling programme) would have suggested far more variability of biomass than occurred in reality.

Conclusions

As suggested above, absence of change is something that marine biologists and fisheries scientists rarely write about. The result of this is that our syntheses and review, being largely based on the published record, are highly biased toward 'variability', and usually fail to acknowledge the mechanisms that generate homeostasis (in this case, latitudinal migrations; see Boëly 1979; Cury and Fontana 1988; Barry-Gérard 1994; Pauly 1996).

That variability in the physical oceanography of an area should generate variability in the biological characteristics of the organisms in that area is trivially obvious. Reporting such 'raw' variability is thus akin to reporting primary data. We believe therefore that the real challenge for fisheries and marine biological research lies in identifying how the organisms we study maintain homeostasis in the face of environmental change (Beyer 1989). In any event, if fisheries can be sustained at all, then they can be only when these largely unknown homeostatic mechanisms continue to work.

Acknowledgements

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The data discussed in this paper were collected by the RV Dr Fridtjof Nansen, a research vessel operated as part of Norway's development aid programme. The ship is named after the explorer, humanist and scientist Fridtjof Nansen (1861–1930) who explored the Arctic on the famous ship Fram (Forward), helped found Norway as an independent state in 1905, was a pioneering zoologist and physical oceanographer, and, after the First World War, worked to resettle several million refugees and prisoners of war. He was awarded the Nobel Peace Prize in 1922. Nansen, pictured here in 1898, possessed an exceptional ability to cut through petty detail to achieve clear, lofty goals. We hold this an appropriate inspiration, and an aspiration for the perspective set out in our paper.

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