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Fisheries Studies in Freshwater and Their Relevance to Marine Systems

by

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Abstract

Fish production processes in freshwater and marine systems should exhibit functional similarities at the micro- and meso-scale, suggesting that some kinds of process studies might be more cheaply and easily done first in freshwater, then applied to appropriate marine data, rather than developed expressly with marine species. Examples of empirical comparative studies and bioenergetic analyses developed in freshwater appear to have relevance to marine systems.

Introduction

It is a common thing for the various fields and sub-disciplines of science to develop in their own ways, semi-independently of related fields, despite the fact they may have much in common. There are many examples of this in the ecological sciences.

Entomology, fisheries, and ornithology, to name but a few examples, all have a common interest in population dynamics; yet I am sure that everyone here is familiar with numerous instances, in population estimation, for example, where each of these sub-disciplines has invented, or re-invented, similar but parallel procedures for dealing with common problems. Many other examples could be given.

This kind of duplication of effort may seem wasteful and unnecessary but, unfortunately, I suspect much of it is unavoidable. Our human failing is that there is a limit to the breadth of knowledge we can individually encompass, while still exerting sufficient depth of understanding to contribute significantly to a specific field.

This is a relative problem, of course; to maintain full and useful communication between fisheries scientists and agronomists, for example, would be a more difficult undertaking than between freshwater fisheries scientists and limnologists. Even so, one of Frank Rigler's (1982) last contributions before his untimely death was to decry, with justification, the lack of communication between the latter two fields.

My task here is to deal with what may seem an even finer distinction; namely, the state of communications between freshwater and marine fisheries scientists. More specifically, my assignment is the unsymmetrical one of considering some of the ways marine fisheries science might benefit from closer attention to its freshwater counterpart. Those who enjoy symmetry I suppose might hope that the next general meeting of AFS, or EIFAC, or the like, will consider the mirror image of my concern today.

Understandably enough, I think there are ways in which we, as marine fisheries specialists, could usefully pay as much attention to the work of our freshwater colleagues as possible. Were it otherwise, I hope I should not have the temerity to take up your time today.

In brief, what I want to do is first, identify what I consider to be some salient differences between marine and freshwater fisheries analysis; second, to review specific instances of freshwater studies we could exploit to our benefit; and finally, to draw some general conclusions from these considerations.

Problems of Scale

A priori, consider some fundamental differences between freshwater and marine fish production systems. Some of the most obvious differences seem to me the least important. Salinity, for example, and species diversity are often higher at temperate latitudes in the sea than in freshwater systems, but while obvious, these do not seem to constitute fundamental ecological differences, although they do make freshwater systems less complicated. In principle, qualitative ecological properties do not necessarily depend on quantitative differences.

Size, on the other hand, does seem associated with a major source of differentiation, but one which is itself complex. There are processes which operate in the northwest Atlantic, warm core rings and frontal systems, for examples, which simply do not exist in freshwater lakes, no matter if they are as large as Baikal or Superior. It is not sheer geographic scale, in itself, which concerns us here. Rather, it is that large geographic scale permits physical phenomena to occur which cannot be realized at lesser scales, and these in turn affect the performance of the biological production systems embedded within them.

At the micro-scale, turbulence phenomena are basically the same between freshwater and marine systems, although the former do not often manifest salinity-dependent phenomena such as salt fingers. Similarly, meso-scale phenomena such as Langmuir convergences, thermoclines, and the like, are basically much the same in either realm. It is only at the macro-scale, when we pass beyond the effects of major current structures, thermal bars, and similar phenomena which are seen only in the largest lakes, that we transcend freshwater system behaviours and enter some uniquely marine classes of phenomena.

My point, accordingly, is that freshwater and marine production systems possess many attributes in common, at what I have called the micro- and meso-scales of physical processes. It is only at the macro-scale, where phenomena such as fronts and rings are observable, that the two seem conspicuously different. Freshwater and marine fisheries scientists, accordingly, ought to exhibit more common interests than often seems the case.

In the freshwater realm, fisheries science and physical limnology seem to be more comfortably married than are their marine counterparts. Notice I did not say freshwater fisheries scientists and limnologists, for that touches on Rigler's (1982) brief, and I agree the scientists themselves have too often gone their separate ways. The distinction, as Larkin (personal communication) has pointed out, is that physical limnology, owing to the limited scales it must deal with, is relatively simple enough that, for practical purposes, the fisheries analyst can often do what is needed without specialist help. Because of the expanded scale of the system, this is less often true for the marine fisheries scientist.

Perhaps for the reason of relative simplicity, freshwater fisheries science impresses me as often more comfortably attuned to its physical milen. Over the several orders of magnitude spanned by the progression from a 5 ha pond, to a 50 ha lake, to the much more sizable dimensions of, say, the Laurentian Great Lakes, freshwater fisheries science has, in my view, dealt more readily and directly with the physical processes that affect fisheries production. The kind of correlational analysis offered by Fry and Watt (1957) for a simple freshwater fishery, for example, was only really achieved in marine fisheries two decades later, owing to the courageous efforts of Sutcliffe and colleagues (e.g., Sutcliffe et al. 1977) in a system that is larger by many orders of magnitude.

Meanwhile, the environmental correlation first reported by Fry and Watt (1957) has been pushed much further. Shuter et al. (1980) and MacLean et al.

(1981) have provided a remarkable investigation of the association of environmental temperature with recruitment variability in smallmouth bass. Their analysis of the physiological basis for the temperature effect showed that two critical periods in the early life history accounts for much of the variability in the ensuing recruitment. The first period lasts from the egg stage to the development of actively foraging larvae, the second period extends over the first winter, when the young must subsist on accumulated energy reserves. Their approach, of pursuing an empirical observation to its physiological basis, is one that would lend itself to marine recruitment studies.

But I have dwelt long enough on the environmental problem, per se. There is an associated factor that simplifies, in a sense, the freshwater scientist's task. This concerns the distinction between time series and ensemble averages. The marine scientists might well envy the freshwater colleague who can, at times, select suites of more or less comparable lakes that can be treated, in a statistical sense, as a set of replicates. It is this comparative attribute that has allowed freshwater scientists such as Ryder (1965), Jenkins (1982), and many others, to deal successfully with their assigned problems, in an explicitly empirical way that is less often available to marine fisheries specialists. Comparative studies, except in such minor areas as coastal embayments, are not easy to design in marine systems, owing to the lack of obvious boundaries spearating the various marine stocks.

It seems to follow that, having identified at least three major advantages enjoyed by freshwater fisheries scientists, namely the reduced scope of physical phenomena that affect such systems and the more frequent simplicity of the species assemblages, ease of stock separation, and the associated ease of comparative studies, that freshwater fisheries science might have something useful to offer its marine counterpart. In my view, this is true, and I turn now to that consideration.

Freshwater Science

There are limits to everyone's patience, and I shall not abuse yours by attempting an extensive review of the relative strengths, as I see them, of freshwater fisheries science. Instead, I have selected two general areas for a brief survey, which I hope will provide adequate underpinnings to support the ensuing conclusions I want to leave with you. These are by no means the only examples I could use; indeed, I suspect many of you here would have chosen differently from the potential list, assuming you would seek to support the same conclusions. I do hope, however, the examples suffice to support my thesis.

Production Regulation

A basic problem, or set of problems, that all fisheries scientists face is that of reaching a predictive understanding of the fish production process. In some ways, marine and freshwater scientists have approached the problem in similar ways. Both groups, for example, have looked intensively at variants of the "critical period" hypothesis, whether in Hjort's strict sense or by some looser definition; and both groups have explored numerous variants of Ricker's stock-recruitment model. These and comparable approaches have been about equally rewarding in lake and in ocean.

The characteristic properties of freshwater systems have permitted, however, some additional approaches that are not so easy to apply to large-scale marine systems.

Consider the biologist charged with evaluating the fishery yield potential of a set of many thousand lakes, of which dozens have major commercial potential, and several hundred more a lesser, but significant potential. This example is not a matter for individual cohort analyses, nor is it an idle speculation, by the way, but it is based upon work undertaken by the Province of Ontario in the "Patricia District", a vast area near the western conjunction of James and Hudson's Bays. The approach used typifies the ensemble method I mentioned earlier, which is empirical and comparative in essence. Using regression models, Ryder (1965) was able to devise a simple model, based on the ratio of total dissolved solids to mean depth, the "morphoedaphic index", which accounted for a major part of the yield variability among the lake ensemble. Apart from the study area for which it was actually designed, the procedure has since been applied, successfully, in most continents that possess appreciable lacustrine fisheries (Ryder et al. 1974; Ryder 1982).

In the present context, the question is not so much why Ryder's index is as effective as it has proven to be, but rather, why have marine fisheries scientists not attempted comparable analyses? In fact, there have been limited applications of this same model to marine systems (Ryder et al. 1974), and Hargrave (1973) has offered a comparable model for marine benthic systems. The point remains, however, that marine fisheries science has not as successfully exploited the comparative, empirical approach as have our freshwater counterparts. The difficulties in doing so in the marine environment are of course obvious. But the rewards seem worth the effort. As is shown by the particle spectrum approach of Sheldon et al. (1977).

Thus far, I have dwelt on the advantages of the ensemble approach to analysis. The relatively depauperate species assemblages of northern lakes lends a further useful dimension to this particular advantage of freshwater systems. Johnson (1972, 1976) has exploited this advantage with great success, in dealing with production characteristics of the char and whitefish stocks of northern systems.

There is much of interest in this body of work, but time permits me to consider only one aspect of it, the contrast between exploited populations of terminal predators, and those which are unexposed to fishing mortality. The contrast is marked, in several ways.

Unexploited populations, of lake trout (Salvelinus namaycush) for example, appear to be structured very differently from the exploited stocks most of us are used to. There is, for example, an evident lack of the kind of obvious length-age relationship we are accustomed to observing in exploited stocks. For reasons put forth by Kerr (1979), this observation depends importantly on the feeding opportunities, and ensuing growth efficiencies, available to the trout; the contrast becomes clear by comparison with exploited populations of the same species.

Does this have any bearing on the production characteristics of marine species? In my view, it does. In many ways, the Atlantic cod is a close functional counterpart of the lake trout. Unlike the lake trout, however, unexploited populations of cod are rare, or at least, have rarely been reported in the scientific literature. The landlocked population of cod in Ogac Lake (Patriquin, 1967) is an interesting exception. In fact, comparison of this unique cod population with the population characteristics of Johnson's lake trout stocks suggests many similarities, the most striking of which is the absence of any obvious length-age relationship. So striking is the absence that Patriquin (1967) refused to calculate a growth curve for the Ogac cod.

In brief, the conclusion I would draw here is that we can learn much about the dynamics of Atlantic cod, and their response to fishery exploitation, by studying the responses of their freshwater counterparts, the lake trout. And I suspect the answers we would get, and obtain much more cheaply, would be about equally applicable to the marine environment. The point I wish to draw to your attention is that important marine stocks, of cod for example, have freshwater analogues that we can learn from in cheaper and simpler ways. The ecological principles are the same, but the sometimes confounding complexities are not so serious in freshwater systems.

Bioenergetics

A second, related area I should like to briefly comment on is the recent progress that has been made in bioenergetics of freshwater fisheries. This field is one that has developed primarily with work on the physiology of freshwater and anadromous species, although more limited work with marine species has been done.

The strength of the freshwater work is two-fold; it rests in the utility and relative simplicity of the models that have been developed, and in the depth of physiological knowledge of the species concerned.

The power of the available models is shown by a recent evaluation provided by Rice and Cochran (in press) in which they use an independent data set, of high quality, to test a representative member of the current class of models. Their rigorous and extensive evaluation confirms the validity of the specific model they test and furthermore, strongly implies similar capabilities for related models. Clearly, freshwater bioenergetics has reached a stage of maturity and utility.

Marine applications, in my view, have not reached the same stage of maturity because of the lesser quality of the physiological measurements that are necessary. This is understandable in some cases, because the marine species of interest are often difficult to capture and maintain in good condition, and because behavioural characteristics (schooling and overwintering behaviour of herring, for example) complicate the laboratory work.

Nevertheless, I believe it is true to say that the majority of important marine species have yet to be investigated for even the most basic parameters, such as temperature or weight dependence of standard and active metabolic rates. For the rest, the work that has been done is usually not of the same standards of quality as are now routine in freshwater. Even for species that have been well-investigated, cod for example, it is still necessary to extrapolate from higher temperatures down to the low temperatures cod occupy in our waters, and extrapolation, as we all know, is a risky business.

I do not wish to minimize the difficulties to be surmounted in raising marine fisheries bioenergetics to the same level of reliability and utility as has been achieved in freshwater, but I do suggest it will repay the effort, and certainly it is an area in which we should pay attention to the work of our freshwater colleagues.

Discussion

In this brief survey, I have quite deliberately gone beyond the theme of trophic relations per se, in an effort to describe some ways in which marine fisheries science might benefit from closer attention to freshwater systems. Our purpose, after all, in conducting trophic studies is to better identify the main causes of production variability in our fisheries, the better to forecast such variances.

My essential point has been that ecological processes do not necessarily respect our arbitrary distinction between fresh and salt waters. For reasons of economy and simplicity, it follows that freshwater analysis at the micro- and meso-scales might often be useful precedents for marine analyses. At the least, we might benefit from closer attention to the literature dealing with these small systems before launching the necessarily expensive counterpart investigations in marine systems.

This is not to say we can glean more than a fraction of the necessary insights from freshwater. At the macro-scale, there is no substitute for work in the marine environment; neither is there any substitute for the species-specific information that must be gathered in situ, to precede any true understanding of our marine production systems. My contention is the more modest one that ecological production processes are sometimes more susceptible of investigation in the freshwater environment.

The obstacles I see obstructing this modest proposal are rather more institutional than scientific. I have met few scientists who were opposed to gleaning insight and information wherever it was available. It is rather more often the case, in my view, that the institutional strictures we follow, often quite unconsciously, flavour our viewpoints. Because, for example, we happen to work for an organization that has the word "marine" in its title, and has large ships at its disposal, and so forth, we could fall into the trap of thinking that every question we tackle must be solved in this way. Sometimes, I suggest, this is not necessarily true. We should consider the possibility that, sometimes, the question we are addressing could be attacked in a preliminary way, at least, in a simpler, freshwater system, and the outlines of an answer will be available more cheaply and readily by this route. And sometimes, of course, we might even find that a colleague with a canoe and a half-meter ring net at his disposal has already provided the kind of lead we seek, in published form. Such is the case, I suggest, in the case of empirical, comparative, fisheries studies as it is in the case of fisheries bioenergetics. These, among other examples not dealt with here, could assist in our task of understanding the processes that result in marine fisheries production.

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