MARINE FISH AND INVERTEBRATES: BIOLOGY AND HARVESTING TECHNOLOGY

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Summary

The technology to understand and harvest fishery resources has expanded markedly in recent times. This expansion in information has allowed the harvesting of new species and stocks. Information is important to preservation and responsible harvesting. For managers and project organizers alike, knowledge is the cornerstone to successful fishery resource utilization. But, the quest is not as simple as it may seem. All fisheries are not identical. Also, information is not easily available, especially in developing countries. However, there is a cornucopia of information available through worldwide

information networks. Fisheries management and science is going through a great scientific revolution in harvesting techniques, environmental analysis and stock development. The refinement and application of emerging methodologies will not only develop and advance the technology but also provide answers to questions applicable to certain fisheries. Such research results will provide the structural framework within which future research may be directed toward elucidating recruitment mechanisms and actual causes of mortality. A pressing problem for conservation and restoration of resources is the lack of sound biological and population information. Information gathered for one community will have implications for fisheries and habitats worldwide. In this chapter, the biology and state of leading fisheries resources are introduced.

1. Introduction

Fisheries of commercial and scientific interest worldwide have come under increased pressure. A fundamental of responsible programs in fishery harvesting is a thorough understanding of parameters in the life history that characterize those populations being harvested. In addition to a fishery's natural history, other critical information concerning life history is based upon growth and trophic dependent factors which determine the demographic characteristics of populations.

Age structured models of stocks are used increasingly in the analyses of harvesting options. These age structured models can include age specific natural mortality rates, fecundity, weight, fishing mortality rates and vulnerability to fishing as well as stock recruitment relationships. Recently, such age structured models have been utilized in management schemes to provide strategies for optimal harvesting. Fishery managers often need to explore the relationship between harvest intensity and some aspect of age specific vulnerability. However, little data presently exists on the population dynamics of many species. This paucity of information is due primarily to the difficulties unique to age determination. Therefore, any improvements in these problem areas will greatly enhance the accuracy of predicted yields and management of stocks being fished—be they vertebrates or invertebrates.

When we stand back from fishery research and look past the modeling of the actual data, we perceive two uncomfortable trends. The first is that fisheries can rapidly decline even when yields are of low proportion to the biomass, or they never increase yield. The second is that once a fishery is at its minimum abundance level, recruitment is often aperiodic so that the fishery is always based on one or two strong year classes against a background of weak recruitment. Both of these situations are unsuitable for equilibrium yield in harvesting. The data required is accurate age and biomass in the pre-recruit level, and much less age and biomass data for modal age stocks. Limited information exists on the population dynamics of many fisheries, especially knowledge about age, growth rates, migration patterns, mortality and longevity. Much of the critical information about these parameters is based upon age-dependent and environmental factors. This information is needed to describe demographic characteristics unique to populations of fish and invertebrates and in the determination of environmental influences on life history events. Any improvements to these problems would enhance our knowledge about biology.

A large part of our research has gone into establishing daily growth increments as obligatory features of otoliths—the calcified structures in the inner ears of teleost fishes—and mean growth increment width as a statistically powerful age estimator. In addition, a comprehension of the structural characteristics, chemical composition, and formation of otoliths would make it feasible to determine the ecological parameters of fish populations. It is probable that fish otoliths function as data storage units and thus provide a chronicle of a fish's physiological and ecological past.

2. New approaches

I suggest a new approach to the evaluation of critical periods during the life histories of fishes and to a lesser degree invertebrates—one which is capable of documenting past environmental conditions encountered by an individual. Specifically, we can take full advantage of the dramatic advances in recent years in the analysis of calcified tissues (especially otoliths) as chronological storage sites of growth and environmental information. We can advance the use of microstructural otolith analyses as well as measures of elemental concentrations at various positions in the otoliths and other calcified tissues, as indicators of past environmental parameters. The patterns and spacings between daily increments of otoliths have been shown to be related to changes in short-term somatic growth and transitions in life history strategies. Identification of high or low growth periods may point to significant changes in survival rates that are crucial to understanding subsequent population variability. The refinement and application of emerging methodologies of analysis will not only further develop and advance the technology, but also provide answers to applicable harvesting problems. Our results may provide the structural framework within which future research may be directed toward elucidating recruitment mechanisms and actual causes of mortality, and will lead the way for similar research on other species. In the following sections, we will argue that a fresh approach to the study of the life histories of fishes—one which takes full advantage of the information stored in otoliths—is urgently needed if we are to proceed with meaningful studies on processes which control population dynamics.

These approaches are essentially management oriented, but they reflect the deeper biological problem of what is the true pattern of growth and how it can be measured. We have a number of studies in progress in different species aimed at translating the coded growth signals in the otolith (increment width, check disposition, protein kind, protein distribution) as well as translating the coded environmental signals (cation and anion densities) of otoliths, scales and other calcified tissues. Information can be used to quantify both the pattern of growth and environment life history of individuals. These studies hold obvious ramifications for management, but I feel very strongly that we can couple environmental history, growth and genotype into a genuine law of nature that explains the relationship between cellular function, individual development, and environment in a simple, quantitative relationship.

New life history technology and developments in acoustic biomass estimation will lead to a cheaper, less labor-intensive harvesting management for what is becoming steadily less profitable wild fisheries resources. As the wild resources decline, aquaculture will rise. Most aquaculture work involves animal husbandry. One area of scientific input is in gene manipulation (gene splicing and gene duplication). In the general excitement of DNA technology, a basic issue has often been overlooked, and has led to the collapse of many gene manipulation groups: the question of which genes to manipulate. A general theory of gene, growth and environment is an essential part of the extension of aquaculture, past the initial animal husbandry phase into the potential profit-increasing gene manipulation stage.

In a fisheries sense, such information is vital to our understanding of the processes underlying recruitment and growth rate and would make it possible to link growth and mortality rates to nutritional and environmental occurrences. But in a general ecological sense, such information is of even greater and more fundamental importance since it will allow us to reconstruct the complex environmental and genetical interactions which are integrated over individuals to provide for both the short term stability and the long term evolution of species and populations.

Pristine aquatic ecosystems are being increasingly impacted due to anthropogenic activity every day. Still, there continues to be a lack of information on the physical and biological dynamics, both on a daily and seasonal basis, of these important ecological resources.

Diadromous species are indicators of the processes affecting energy transfer in aquatic ecosystems. For fishes and invertebrates with "complex life cycles" the link between the hydrography and the growth, survival and recruitment is most critical.

Phytoplankton is the dominant primary producer in most aquatic ecosystem, and may provide important control over recruitment mechanisms in populations. Recent developments in technology using optical remote sensing of ocean color can be employed to assess phytoplankton production and distribution as well as sea surface temperature along large spatial and temporal scales. Optics are used to determine differences in the relative reflectance of blue and green-yellow wavelengths, such that the relative reflectance of blue and green-yellow wavelengths is inversely proportional to chlorophyll-a concentrations. In this manner, remote sensing can provide a time series of information on phytoplankton abundance and temperature, movements of water masses containing different concentrations of phytoplankton, and different temperatures can be tracked along both temporal and spatial axes.

Sea surface temperature and currents may have important consequences to the distribution, development, growth and harvesting of fish and invertebrates. Lowered temperatures can result in reduced growth, consequently increasing vulnerability to predators and harvesting while decreasing its prey capturing abilities. Transport by ocean currents can carry eggs and larvae to or from areas favorable to survival.

Remote sensing data may be used to describe distribution and movements. Such images have begun to be used in recruitment studies in central California to suggest that cross-shelf transport was important to successful recruitment of intertidal barnacle populations. Many fish species have been shown to change their spawning grounds in response to environmental changes and/or population size (e.g. sardines in the western and eastern boundary areas of the North Pacific, the eastern boundary of the South Pacific, and both the northern and southern boundaries of the eastern Atlantic). The linkage of the shift of spawning ground with environmental changes and population level can reveal some aspects of species-environment interactions and adaptation strategies.

Thus, we may be able to elucidate the complex relationships between large and small-scale physical and chemical features with biological resources.

The continued health of fishery populations is of substantial scientific and economic importance. To understand the dynamics of populations and to provide the best information for their management and harvesting, it is necessary to increase the level of knowledge of their life histories. If the biological and ecological functions of communities are to be interpreted, the biology of individual species must be elucidated. The information on individuals can be applied to predict population characteristics.

Available statistics (see Table 1) point to trends in yields that are either static or declining. While these data yearned some updating, they do demonstrate our efficiency in harvesting fishes and invertebrates. This efficiency will increase with technology, but yields most likely will not. An example in harvesting efficiency with increases in technology is evident with China where the amount of fishes, crustaceans and molluscs increased from 4 672 287 metric tonnes in 1987 to 14 552 262 in 1999.

A: Global harvest totals

	1996	**1999**
All species, all ISSCAAP groups, world total	94,714,442	94,086,236
Marine Fishing Areas	87,316,181	85,825,995
Marine Fishes	73,272,414	70,195,270
Molluscs	6,037,057	6,793,876
Crustaceans	5,025,435	5,762,949
Regions		
Northern	39,120,936	38,771,339
Central:	25,210,025	26,475,331
Southern:	21,312,058	18,762,143
Pacific:	54,120,587	52,312,008
Atlantic:	25,513,130	23,260,968
Indian:	8,009,302	8,435,837
Southern:	113,147	123,548
Pacific NorthWest:	23,155,835	23,685,453
Pacific SouthEast:	17,015,299	14,111,344
Atlantic NorthEast:	11,032,331	10,489,260
Pacific West Central:	8,790,333	9,714,837

B: Top 12 countries

	1996	**1999**
China:	12,153,722	14,552,262
Peru:	9,485,697	8,389,440
Chile:	6,634,841	4,992,062
Japan:	5,807,178	5,077,868
USA:	4,944,254	4,690,963

Russian Federation:	4,441,786	3,832,089
Indonesia:	3,210,821	3,846,560
Thailand:	2,760,248	2,732,890
India:	2,825,639	2,627,367
Norway:	2,648,119	2,619,559
Philippines	1,603,605	1,725,587
Malaysia	1,106,787	1,241,220

C: Major groups

	1996	1999
Herrings, sardines, and anchovies:	22,310,845	22,712,915
Jacks, mullets, sauries:	11,063,936	7,661,568
Cods, hakes, haddocks:	10,769,058	9,405,218

D: Leading species

	1992	1996	1999
Anchoveta	6,157,269	8,863,714	8,723,265
Alaska pollock	4,986,664	4,548,585	3,362,473
Chilean jack mackerel	3,376,607	4,378,843	1,423,447
Atlantic Herring	1,546,449	2,328,514	2,403,543
Capelin	2,115,140	1,527,422	904,840
South American Pilchard	3,057,073	1,493,936	442,690
Skipjack tuna	1,437,063	1,583,942	1,976,479
Atlantic cod	1,185,017	1,340,831	1,092,859
Largehead hairtail	829,797	1,282,698	1,418,944
Japanese Anchovy	662,540	1,254,487	1,820,259
European Pilchard	1,156,762	996,334	901,427
Yellowfin Tuna	1,154,458	1,082,686	1,258,386
Japanese Pilchard	2,488,533	430,837	515,477
Sandeels		858,630	762,249
Argentine Hake		681,999	372,039
European Sprat		671,616	684,164
Scads		607,686	502,590
Atlantic Mackerel		560,494	610,947
Croakers		523,999	599,423
Gulf Menhaden		491,612	694,242
Atlantic Horse Mackerel		474,754	322,207
Indian Mackerel		399,938	302,387
Haddock		361,984	249,317
Saithe		355,697	339,987
South Pacific Hake:		323,470	141,053
Patagonina Grenadier		379,015	309,723
Atlantic Menhaden		304,665	208,000
Atlantic Herring		292,845	281,505
Indian Oil Sardine		223,355	209,866
Blue Crab		1,000,000	91,851

Japanese Flying Squid		715,908	497,887
Argentine Shortfin Squid		656,481	1,091,299
Yesso Scallop		276,406	305,510
Ocean Quahog		180,114	147,933
Atlantic Surf clam		155,584	142,370
Akiami Paste Shrimp		460,871	598,602
Northern Prawn		287,831	338,969
Jellyfish		265,325	402,206
Southern Rough Shrimp		167,723	403,027
Gazami Crab		303,170	284,851
Ocean Quahog		173,685	144,366
Atlantic Surf Clam		154,380	142,067
Blue Mussel		117,550	121,964
American Cupped Oyster		111,682	89,714

Sources: www.fao.org/fi/statist/fisoft/fishplus.asp
ftp.fao.org/fi/stat/windows/fishplus/capdet.zip

Table 1. Statistics (in metric tonnage) for fish and invertebrates harvested worldwide.

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Biographical Sketch

Richard Radtke received his PhD in Marine Science from the University of South Carolina, USA. He is a full research professor at the Hawai'i Institute of Geophysics and Planetology in the School of Oceans and Earth Sciences and Technology at the University of Hawai'i. His research topics mainly focus on ocean fish demography, migration and age determination.