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Ashaq Hussain Bhat
Senior, Assistant Professor, Department of Zoology, Govt. Degree College Women, Anantnag, Jammu and Kashmir, India

Corresponding Authro:
Ashaq Hussain Bhat
Senior, Assistant Professor, Department of Zoology, Govt. Degree College Women, Anantnag, Jammu and Kashmir, India

Stock assessment in river system: Brief outline and bibliography: Literature review

Ashaq Hussain Bhat

Abstract
Rivers are an important part of the life cycle of so many aquatic species including the fish fauna as they provide the necessary medium for survival, growth, reproduction. It also provides other gaseous constituents necessary for the maintenance of the equilibrium and survival. Rivers as part of lotic ecosystem also harbours a very good percentage of fish fauna and other aquatic species. Fish provide important source of protein and job opportunity to a lot of families including the Educated youth and thus easing burden on the Government. But from last one-decade (due to the rise and shift towards the technology sector) fisheries are disrupted or under severe stress from changes in riparian structure and function, chemical and organic pollution, overfishing and destructive fishing practices, alterations in hydrological regimes and global climatic changes. So present study was made to access the stock assessment in river systems.

Keywords: River, fish, lotic, protein, pollution

Introduction
Tropical freshwater commercial and artisanal fisheries provide extremely important sources of protein and incomes for millions of people in developing countries. Today, these fisheries are disrupted or under severe stress from changes in riparian structure and function, chemical and organic pollution, overfishing and destructive fishing practices, alterations in hydrological regimes and global climatic changes. Resource assessments and economic evaluations of all inland fisheries resources are necessary in developing long-term, sustainable fisheries programs.

This outline and annotated bibliography will provide references describing key aspects relating to conventional and alternative methods of stock assessment techniques used in tropical riverine or other lotic environments. The application of standard fisheries assessment methods to tropical river systems does not have the widespread history as compared to temperate inland or marine fisheries. This outline is a preliminary bibliographic study on those techniques, which may prove useful in assessing river stocks. Methods and examples may aid in developing relevant and efficient sampling and assessment programs for community-based artisanal and commercial river fisheries. Emphasis is placed on examples from lotic systems in South America and Africa. References in Faulkner and Silvano, (Marques, 1995, Petrere, 1989 and Silvano & Begossi, 1998, 2001) [38, 8, 23] specifically refer to fisheries management in Brazilian lotic environments. Willoughby, 1979, and references by Welcome, outline sources of variability in stock assessment efforts primarily in African riverine environments. Studies from other climatic zones or geographical regions are included if relevant.

The idea behind a stock assessment, historically based on steady state or equilibrium relationships between fish production and permissible (non-depletive) harvest levels, is to determine rates of recruitment into a fishable biomass and the growth and mortality (differential rates of exit) of an exploited stock. This information can provide the basis for long-term yield prediction**.** But uncertainty pervades upwards from assessment to management. The assessment must account for the untenable assumptions of the “steady-state” view of fishery resources. A complete stock assessment is a stepwise process. Steps include; defining biological and geographic extent of the stock(s) in question; choosing data collection methods and collecting the data; choosing an assessment model and its parameters and conducting the assessment; specifying performance indicators and performing alternative action evaluations; presentation of findings (NRC, 1998) [4].

Stock assessment models attempt to predict changes in biomass and productivity based on yield data collected from a target fishery. Stock assessment relies on the estimation of many parameters, which require a lot of data from historical fishery and independent biomass surveys (Pitcher and Preikshot, 2001) [53]. Fundamentally, stock assessment models are based on rates, which imply time, which is why an estimate of fish age is required. Conventional stock assessment techniques employed in tropical lotic systems often use length-based data because the technology necessary for direct age determination i.e. otolith/scale preparation and analysis is unreliable, expensive or not available. Length-based analyses require a lot of data, and length is not a desirable variable, as its relationship to age is non-linear, but length data is easily taken in the field, with simple measuring boards and recording forms. A relationship between length (size) and age is required (Kolding references in Mosepele and Kolding 2003) [40]. Length-based assessments are valid over a narrow time frame and if measured parameters are relatively constant. NRC, 1998 conclude that stock assessments do not always provide enough information to evaluate data quality and to sufficiently estimate model parameters. The best index of abundance is the one that can control for factors which increase uncertainty (ie. change in fisher behavior, change in gear type/ seasonal coverage.

"The simulation study demonstrated that assessments are sensitive to underlying structural features of fish stocks and fishery practices, such as natural mortality, age selectivity, catch reporting and variations in these or other quantities"(NRC.1998) [41].

The NRC study recommends single species stock assessments, that include wherever possible multi-species interactions. A key problem outlined in the NRC simulation is that with many SA models there is a significant lag in detecting population abundance trends. Improved and increased data collection is one of recommendation to mitigate this. This lag is related to the models' inability explicitly express uncertainty. The incorporation of uncertainty into stock assessment models is strongly recommended.

A research study on the use and management of riverine fish populations should begin primarily with an thorough historical overview of the development of the local riverine fishing activities and strategies (targeted species, fisher demographics, gear types and effort) in the context of changing watershed landscape uses and how those changes affect the evolution of social institutions influencing fisheries management and harvest decisions. A conventional stock assessment can begin to describe ecological attributes and population characteristics such as species composition, age-length distributions, growth and mortality factors (density and density in dependent), recruitment, potential yields, catch-per-unit-effort, (CPUE). Theses indices begin to tell you what is there, an idea of the size and age class distribution of what is there, the impact of fishing as a mortality factor, how quickly young fish are "recruited" into the fishable biomass and if historical data exists (often in developing countries there is a paucity of time series data for fish catch statistics) how present day fishing conditions are impacting population structure as compared with past effort. This is very important because fishing pressure can alter the size structure of a population often removing the larger, longer lived slow reproducers (high value species) with less valuable, small, rapid reproducing species (Welcomme, 1992) [68]. A key concern is often establishing or verifying the state of the presently exploited fish populations with respect to local perceptions. There can be discrepancies between how local people perceive their stocks and their actual condition (Mosepele and Kolding, 2003) [40]. Catches can exhibit temporal fluctuations based on changes in effort (Gulland 1983, Hillborn and Walters, 1992 and Welcomme, 1992) [29, 32, 68]. Length-based stock assessment models require a lot of data over a short time frame, so for simple logistics fishermen should be involved in data collection (Ticheler *et al.*. 1998) [64]. This should also serve as an exercise to begin to alleviate any mistrust between researcher and fisher folk.

Assessment techniques designed with assumptions for single-species, temperate zone marine applications are applied/adapted to use in multi-species, highly variable tropical fisheries often with ambiguous results. Welcomme, 1999 [69], makes the key point, that in highly, variable, multispecies tropical riverine environments it is impractical to try and extrapolate from a single species target analysis, due to the plethora of interspecific interactions. Multi-gear, multi-species fisheries, with high seasonal and inter annual variation will react in unpredictable ways as a result, of a diverse fishing effort interacting with a complex species assemblage and the highly variable abiotic environment found in rivers, river-dependent lakes and reservoirs. Sampling regimes often include data from fish landing sites, (official, illegal, centralized dispersed) with catches weighed (both by researcher and fishermen) and sorted by species (diversity index) length weight. The Brazilian (IBAMA-Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renovaveis) –German (GTZ) field project (IARA) collected data daily from fish markets at Santarem, Brazil. Fish were caught by a number of different gears, from gillnets to arrows and harpoons. Total length of each fish [for statistical accuracy/precision, 1 type of length; standard, fork (compressed or not) or total and consistent length frequency nodes must be used throughout the data collection], weights (to the nearest 10-50 g depending on fish length). Random samples of gonads were taken to assess reproductive condition (Ruffino and Isaac, 1995) [58]. Table 1 in Darwall and Allison, 2002 [20] lists options for common stock assessment and management tools. The reader is referred to the following incomplete yet representative list of texts and manuals which outline classic stock assessment methods for data collection, equations and algorithms, data analysis and modeling (Holden and Raitt, 1974; Pauly, 1980; Anon, 1981; Gulland, 1983; Welcomme, 1985; Pauly and Morgan, 1987; Sparre, Ursin and Venema, 1989; Polovina, J.J. 1990, Crul, 1992; Gulland and Rosenberg, 1992; Hilborn and Walters, 1992; Gayanilo *et al.* 1995, Gallucci *et al.* 1996, NRC, 1998, Funk *et al.*., 1998, Hart and Reynolds, 2002) [33, 3, 29, 52, 30].

Holistic Ideas and Inclusive Approaches

A fishery is a human undertaking, existing in a multi-discipline environment with ecological, social and technological implications. Conventional stock assessments focus on the ecological and sometimes the economic aspects of the fishery, the evaluation of the fishery with respect to all the aforementioned disciplines is required in order for effective and sustainable decisions. (McGoodwin, 1990 in Pitcher and Preikshot, 2001) [53].

In a discussion of new or holistic approaches to fishery assessment and management in any environment the writer assumes the necessity of a conjunction between effective social and natural science methods in data acquisition, analyses, information management and subsequent decision-making.

These undertakings will require one to have the hedgehog's clearly defined and directed objective coupled with the fox's tool box of many creative and cunning approaches! (Gould, 2003) [28].

Multi-species, tropical riverine environments are complex systems. Many species, both targeted and non-targeted species interact amongst themselves, with fishermen of different gear types and social standing all within a dynamic abiotic (hydro-geomorphic) environment. Charles, 2001 [12], pg. 223 lists sources of complexity in fishery systems, although from marine examples they will apply in any complex aquatic system. Key to tropical river systems are multi-species and ecological interactions, multiple groups of fishers interacting with households and communities and multiple gears and technical interactions and conflicts. De Merona, 1990 [19], in two case studies of Amazonian fisheries, showed high seasonal as well as inter-annual variations in yield that were not related to effort. Catchability was related to water volume determined by the seasonal flood pulse patterns. Environmental variations can affect fish yields. For example, the velocity of the flood pulse can affect the extent of penetration of fish into flooded forests, thus affecting yields (Petry, 1989 in De Merona, 1990) [19]. The possibility of climate-driven fish production, independent of effort should be considered in tropical inland fish stock and livelihood assessments.

In any fishery there will always be a need for a process to project yields, predicated on a predetermined stock condition. The biological complexity and the ecosystem nature of the fishery can be first addressed through multiple-species stock assessment. Interactions among species, i.e. trophic relationships, can be important in determining stock compositions. Multi-species stock assessments can be financially and labor intensive (see Gulland's comments, pg. 227 in Charles, 2001) [21]. In order to understand and control key interactions, we begin to simplify; removing complexity, interesting emergent properties and thus validity. The management of human interactions with the fishery is a key concern. The modification and combining of single/multispecies techniques or ecosystem structure and function (habitat) assessments are required for assessing tropical riverine stocks. Money, labor and creativity are key determinants of which approaches are taken. These new approaches to assessment will also take into consideration how the species are used or flow within the social context and livelihoods of community members. As we attempt to assess the status and use of the fish components of these complex systems, the hybridization of the most suitable analytical techniques and processes from the natural and social sciences will be required. Information from accurate data analyzed through conventional length or age-based stock assessment methods where feasible, and the human data collected through creative, participatory appraisal techniques must be blended to give a broad picture of resource condition with respect to its present and possible future uses. Pitcher and Preikshot, 2001 [53] and references within, describe a multi-disciplinary rapid appraisal approach (RAPFISH) for evaluating inter and intra fishery sustainability. This is a possible integration of the natural and social sciences via quantification of key explicit sustainability attributes. RAPFISH can provide helpful signals about shifts and track changes in the sustainability status of stocks. RAPISH requires explicit delineation of "Good & Bad" attributes of the fisheries under study. RAPFISH may serve as a "triage" for the state of fisheries in order to foresee future problems before biological or socio-economic collapse. The question is can these environmental changes be detected early enough to prevent a flip in ecosystem attributes beyond a bifurcation point resulting in an undesirable fishery in which there may be no return? RAPFISH has been applied to tropical African lakes and artesanal marine fisheries. The applicability of RAPFISH to tropical river fisheries should be ascertained.

The complex nature of these resource systems will require creative and adaptive methods that include the participation of the key communities and their members, incorporate both conventional data requirements (ex. accurate/precise sampling of fish lengths and weights, species identification etc.), social science descriptors and analyses such as RRA, PRA (rapid and participatory rural appraisals derived from farming systems research and rural development, see Chambers, 1997 in Berkes *et al.* 2001) [10] as well as the inclusion and preservation of relevant and unbiased traditional ecological knowledge (Poizat and Baran, 1997 [54]. This is a tall order! Malvestuto, 1989 [37] lists the broad social values or accounts relevant to large rivers as

1. The value (Health) of ecosystem.
2. Nutritional or dietary value of the harvest.
3. Sociocultural values and
4. Economic values.

[For a comprehensive discussion on these considerations and techniques in stock assessment, information management and project implementation and evaluation for small scale fisheries the reader is directed to Chs.4, 5 and 6 in Berkes *et al*. 2001] [10]. The recognition and incorporation of the knowledge, views and participation in data collection (the fishermen's daily catch) of key fishing people (from old-timers to new enthusiastic fishers) is a practical and cost effective way to conduct ecological studies and an essential element of community-based resource assessment (Poizat and Baran, 1997 [54] and references within, especially R. Johannes, for further discussions on the inclusion of fishing community knowledge in fisheries management).

The combination of community participation, rigorously applied science and the incorporation of traditional ecological knowledge will provide the adaptive capacity to accurately assess the status and resilience of the resources. This assessment will contribute to the determination of baselines, which form the building blocks of a long-term community-based management program. Pauly, 1999 makes the important point that regardless of the fishery management program, whether market-based, co-management or on specific types of governance arrangements, the local "communities living in real places and exploiting stocks that have places as well" must be included in any research and management initiatives. This capturing and working with the local perceptions of place will be crucial for successful fishery management. Apostle *et al.* 1985 p. 256 (quoted in Charles, 2001) [4] note "it is essential to understand how inhabitants perceive their present-day existence. Do people continue to live in these small villages by choice or from lack of alternatives? Is work satisfaction a prime reason for wishing to remain within the community, or is the work secondary to other factors related to place?" Table 3.4 in Charles 2001 lists relevant demographic, sociocultural, economic, institutional and environmental factors related to a fishing communities' sense of place. These factors should be incorporated along with fishery concepts such as optimum yield in future community-based fisheries management (Malvestuto, 1989) [37].

The assessment of tropical, small-scale, artisanal fisheries we require the use of diverse fishery information types; data which is not always applicable in more biological, numerically-driven models and analyses, such as traditional ecological knowledge on spawning and feeding habitats. Faulkner and Silvano, 2001 [62], discuss the importance of realizing that traditional fisheries knowledge held in the collective wisdom of fishing communities can be extremely important in establishing new scientific knowledge or verifying western scientific findings. Diegues, 2001 [22], examines the relationship between traditional fisheries knowledge and contemporary Brazilian fisheries management, although a marine example, he describes "spheres of local knowledge" which can include valuable information on classification of aquatic species, fish behavior, taxonomy, patterns of reproduction and migration, and the feeding ecology of different species plus knowledge of habitats, local weather patterns and the differential use of fishing techniques and gears in different habitats. The inclusion of this time tested knowledge as well as fishers views and ideas into the experimental design and the implementation of the sampling regime should be done whenever possible, being cautious of inherent experiential or cultural biases. These new approaches focus on the assessment of the whole fishery rather than concentrating on just maximizing biological or economic fish production. Information must be acquired and used in the context of a well-designed sampling plan with clear objectives for how the data will be used (Berkes *et al.* 2001) [10]. Assessments of small-scale, artisanal fisheries in developing countries will often be constrained by financial and manpower limits as well as many local conflicts so simple, efficient/rapid data collection methods are essential. Bayley 1981 and Bayley and Petrere, 1989 [7] describe methods of using average household fish consumption, census data and population increase rates to determine area fish consumption (Shrimpton *et al.*. 1979 in Bayley, 1981) [7]. These studies correlated well with data derived from fish recording (Petrere, 1978a in Bayley, 1981) [7], with a lower sampling error than conventional approaches, which often have high variances in daily catch/effort and total effort estimates (Bayley, 1989) [8]. They were also easier to implement than monitoring numerous scattered landing sites. Sampling landing sites often must be at specific times and can be inconvenient to busy fishermen. Biases resulting from discards can be important but are often non-existent due their consumption in local markets and villages. In a study of the artisanal fisheries on the Sao Francisco River, Minas Gerais, Brazil; De Camargo and Petrere, 2001 [11], collected data from the headquarters of fishing communities to develop an assessment of financial and ecological status of the fishery to support state and local planning efforts for implementing fishing regulations. An extensive questionnaire was used to interview fishermen in the wet season. They found that the fishermen did not answer all the questions, so it was modified to emphasize only fishing when reused in the dry season, missing data also reduced the number of response. This illustrates the importance of having the flexibility to continually adapt sampling methods to changing conditions. Basic data on fishing gear, variables affecting income generation from commercial sales and the spatial distribution of fishermen were collected. Results showed half of the fishermen practiced subsistence agriculture, 90% had an assistant, the sale of fish was directly to dealers, either at the fisher's homes, or in camps, streets, communities or free markets. Seasonal fuel consumption patterns were determined. With respect to fish landings; the most important species were determined. The fishermen separated the catfish *Pseudoplatystoma coruscans* (Agassiz) based on sexual maturity/size. Wet and dry season catch composition and average landing prices were also determined. Important data was also collected on fishing gears and their seasonal and geographical deployment, transportation (boat type and horsepower/effort), species composition and illegal fishing practices.

This diverse data begins to illustrate the dynamics of the fishery and where regulations, monitoring and enforcement may be concentrated with respect to overall fisheries management (De Camargo and Petrere, 2001) [11].

Assessment of the importance of fish consumption to indigenous peoples are often not carried out due their perceived lack of impact on commercial stocks and the diffuse nature of knowledge spread over the river basin (Bittencourt, 1991 in Batista *et al.* 1998) [6]. Holistic approaches to aquatic resource management can be used to assess consumption by indigenous peoples. The study of fishing practices of Amazonian river people by Batista *et al.* 1998 [6] is an example. Trained, local community teachers and health care workers selected those communities and families to interview. Household demographic and fishing data was collected which provided an overall picture of the role of specific fish species and how effort is spatially distributed with respect to season and the spatial and temporal variation in the patterns of capture, fish use and methods of preservation, that are linked closer to environmental characteristics (proximity to markets) than to their location along the river system.

An interesting case study from the Bangweulu Swamps, Zambia explicitly analyses the feasibility of local fishermen participation in collecting scientific data (Ticheler, *et al*. 1998) [64]. Low sampling returns from experimental gillnet surveys required a marked increase in effort for realistic assessment. Manpower and financial resources were limited and getting in and out of the swamps was difficult. A number of full time fishermen living in the swamps were hired on a monthly fee. The inclusion of all major gears used in the swamps was attempted. Information was kept to a minimum and simple methods were used. A one-day training session was organized. This was to explain background of the data collection; assess their skills at identifying fish species; provide instructions on measuring (fork and total lengths) and weighing (see pg 85 for details on data collection). Monthly supervisory visits were conducted. It was stressed that the quality not the number of records was important; so the quality of the fishermen's data handling was checked along with net condition. The quality of data was checked by plotting simple length frequency against mesh size to generate "plausible" fish catches. The study was very successful with 400,000 records collected in 12 months. Although the data was simple, its volume made it suitable for growth and mortality estimates. Interesting additional data on local catch compositions, CPUE and differential gear/fish length selectivity was also recorded. This data coupled with a previous total gear inventory allowed for a full-length stock assessment. It was also relatively inexpensive. The study

showed the complementarities of the experimental gillnet survey and the fishermen's collected data. The extensive study by Poizat and Baran, 1997 [54], to assess the accuracy of local fishermen's knowledge on the spatio-temporal patterns of fish assemblages, confirmed the accuracy and relevance of the ecological knowledge possessed by local fishermen and encourages ecologists to incorporate this knowledge into defining their sampling areas and designs.
The most effective tropical river stock assessment will probably be a hybrid of those methods which best account for surprise and uncertainty (environmental heterogeneity), accurately reflect important species traits and foster community participation in research design, data collection and subsequent management and livelihood decisions. This with the hedgehog's permanent goal of fostering, happy and sustainable river futures.

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