Reservoir Fishery Management and Development in Asia

Proceedings of a workshop held in Kathmandu, Nepal, 23–28 November 1987
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Editor: Sena S. De Silva
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/Fishery development/, /reservoirs/, /inland fishery/, /fishery management/, /Asia/ -- /fish production/, /freshwater fish/, /fishery resources/, /conference reports/, /lists of participants/.

UDC: 631.21:627.81(5) 
ISBN: 0-88936-515-6

Technical editor: W.M. Carman

A microfiche edition is available.

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ABSTRACT

This publication presents the results of an IDRC-funded workshop held in Kathmandu, Nepal, 23-28 November 1987. Representatives from 15 countries reviewed the status of reservoir fishery research in Asia under the following topics: existing fisheries, limnological aspects, biological and resource aspects, management aspects, and culture. Papers were presented on these topics, but the discussion sessions were the main element of the workshop. Summaries of these discussions as well as a series of general recommendations that were generated during the final discussion are presented in this book. The potential for increased fish production in reservoirs and the need for early involvement of fisheries scientists in the planning and preimpoundment studies before dam construction are emphasized.

RÉSUMÉ

Cet ouvrage présente les résultats d'un atelier financé par le CRDI à Katmandou, au Nepal, du 23 au 28 novembre 1987. Des représentants de 15 pays ont examiné l'état de la recherche sur l'élevage du poisson en étangs en Asie, en particulier les aspects suivants: les systèmes actuels, les aspects limnologiques et biologiques, les ressources, la gestion et l'élevage. Des exposés ont été présentés sur ces sujets, mais les discussions ont été l'élément le plus important de l'atelier. L'ouvrage présente également un résumé des discussions ainsi que les recommandations générales issues de ces discussions. On met l'accent sur la possibilité d'augmenter la production de poissons en étangs et la nécessité pour les ichthyologistes de participer très tôt aux études de planification, notamment de la mise en étangs du poisson, qui précèdent la construction d'un barrage.

RESUMEN

Esta publicación presenta los resultados de un taller auspiciado por el CIIID en Kathmandu, Nepal, del 23 al 28 noviembre de 1987. Representantes de 15 países analizaron el estado de la investigación sobre pesquería asiática en embalses desde los siguientes ángulos: pesquería existente, aspectos limnológicos, aspectos biológicos y de recurso, aspectos de manejo y cultivo. Las ponencias versaron sobre estos temas, pero las sesiones de discusión fueron el principal elemento del taller. Este libro ofrece los resúmenes de estas discusiones, así como una serie de recomendaciones generales emanadas de la discusión final. Se subraya el potencial para incrementar la producción pesquera en embalses y la necesidad de una participación temprana de los científicos del área en la planificación y los estudios de apropiación que anteceden a la construcción de represas.
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EFFICIENCY OF TWO TYPES OF NETS FOR SAMPLING MICROCRUSTACEAN
ZOOPLANKTON IN THREE SRI LANKAN RESERVOIRS AND A DISCUSSION
OF SAMPLING METHODS

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8536 VD Oosterzee, Netherlands

Abstract The efficiency of different methods for collecting microcrustacean zooplankton is evaluated in three Sri Lankan reservoirs of different productivity. The catches of two plankton nets (80 and 335-µm mesh) are compared with the catches of the Ruttner bottle, a 2-L volume sampler. Productivity has a pronounced negative effect on the efficiency of the 80-µm mesh hauls. Vertical hauls are always more effective than horizontal hauls, although only ca 50% of the organisms present in the water column of the reservoir are collected. The 80-µm mesh net has a low catching efficiency because of clogging. In the 335-µm mesh net, a high proportion of the smaller organisms are lost through the mesh. It is concluded that, for monitoring studies, vertical net hauls can be used after calibration; however, for population dynamics and production studies, a volume sampler should be used. Sampling strategies and samplers to be used in monitoring or population dynamics and production studies are discussed in detail.

As part of a pilot program for the project on the population dynamics and production of microcrustacean zooplankton (Vijverberg et al., this volume) several different sampling methods were carried out simultaneously to collect zooplankton in three Sri Lankan reservoirs during December 1985. This additional sampling program had three main objectives: firstly, for calibrating the routinely used horizontal net (335-µm mesh) hauls; secondly for comparing the efficiency of the horizontal net haul with that of the vertical net haul; and, finally, for comparing the efficiencies of the fine-mesh net (80 µm) hauls and the coarse-mesh net (335 µm) hauls.

Materials and Methods

Two types of nets and one volume sampler were used simultaneously for sampling in three reservoirs in Sri Lanka. One net was a simple 85-µm mesh net (mouth diameter, 25 cm; height 49 cm); the second net was an Apstein-type, 335-µm mesh plankton net of 130 cm length, with a cone on the mouth (upper diameter, 16.5 cm) to increase efficiency. With the two nets, both horizontal and vertical hauls were made. For the horizontal hauls, the net was hauled horizontally at a depth of ca 1 m for 20 s behind a boat traveling at a speed of ca 1 m/s. Vertical
net hauls were made from the bottom toward the surface, and the depth of the water column was measured for each haul.

Volume samples were taken with a 2-L Perspex Ruttner bottle (column height, 22 cm; diameter, 11 cm) at the same site where the vertical and horizontal net hauls were taken. Ten samples (total, 20 L) were collected at each depth. In the deepest reservoir (Muruthawela), samples were collected at five depths: just below the surface, 2, 5, 10, and 15 m, which was just above the bottom. In the shallow reservoirs (Tissawewa and Yodawewa), samples were collected at three depths: just below the surface, just above the bottom, and at an intermediate depth. Samples from the same strata were pooled and concentrated by filtration through an 80-µm mesh plankton gauze. One of the pooled samples from Yodawewa was split in two fractions: water was first sieved through an 80-µm mesh filter and then through a 30-µm mesh filter. Most samples were subsampled before counting with a broad-mouth pipette. A minimum of 200 individuals from each sample were counted. For more information on the methods, see Vijverberg et al. (this volume).

The three reservoirs have different dimensions (Table 1). Tissawewa is the most eutrophic in terms of chlorophyll-a concentration, followed by Yodawewa, which is also eutrophic, and Muruthawela, which is mesotrophic (Table 1). For more information about the study area see De Silva and Sirisena (1988).

Results and Discussion

Efficiency of 80-µm Sieve for Retaining Nauplii

The two fractions of the Yodawewa sample were compared. This sample was split into an 80-µm fraction, which was collected with an 80-µm sieve, and a 30-µm fraction, which was collected with a 30-µm sieve after passing through an 80-µm sieve. Nauplii were observed in the 30-µm fraction only. By comparing the total number of nauplii in this fraction with the total number of nauplii in the 80-µm fraction, the efficiency of the 80-µm sieve for retaining nauplii can be calculated. The 80-µm sieve recovers 97% of the nauplii. Thus, this mesh is sufficiently fine for the quantitative collection of nauplii.

Efficiency of the Horizontal (335-µm Mesh) Net Haul

The efficiency of the horizontal (335-µm mesh) net hauls is low and roughly similar in the two reservoirs (Table 2). The mean

Table 1. Dimensions and mean chlorophyll a content of three Sri Lankan reservoirs.

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Surface area (ha)</th>
<th>Maximum depth (m)</th>
<th>Chlorophyll a content (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muruthawela</td>
<td>516</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>Tissawewa</td>
<td>234</td>
<td>5</td>
<td>31</td>
</tr>
<tr>
<td>Yodawewa</td>
<td>488</td>
<td>4</td>
<td>14</td>
</tr>
</tbody>
</table>
efficiencies for all the taxa are 15% for Muruthawela and 10% for Yodawewa. There are significant differences in efficiency between taxa. Larger species such as Diaphanosoma spp., Moina micrura, and calanoid copepods have relatively large efficiencies; small species such as Ceriodaphnia cornuta and the cyclopoid copepods show low efficiencies of around 1%. This is obviously because of the coarse mesh used; however, the vertical zooplankton distribution, with relatively low densities in the surface layers, may also play a role (see Vijverberg et al., this volume).

Comparison of Efficiencies

The 335-µm net is usually less efficient for small species (e.g., Ceriodaphnia cornuta and cyclopoid copepods), but is relatively efficient for large calanoid copepods. Vertical hauls are generally much more efficient than horizontal hauls (Table 2). The largest differences in efficiency are observed when we compare the 80-µm mesh horizontal haul in eutrophic Yodawewa (mean efficiency, 1%) with the 80-µm mesh net vertical haul in the same reservoir (mean efficiency, 68%). Conversely, the 80-µm mesh net horizontal haul in the mesotrophic Murathawela is much more efficient (mean efficiency, 37%). This difference is likely due to the severe clogging of the 80-µm net during the horizontal haul in Yodawewa; this occurred to a much lesser degree in Muruthawela because of the much lower seston concentration. More clogging is to be expected in the horizontal haul in Yodawewa because, during this haul, the net is towed over a distance that is 13 times longer than that of the vertical haul.

Effects of Mesh Size on Efficiency

Generally, only minor differences are found between the efficiencies of the vertical 335-µm mesh net haul and the vertical 80-µm mesh net haul in the same reservoir. The relatively large

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Calanoids</th>
<th>Diaphanosoma</th>
<th>Moina</th>
<th>Ceriodaphnia</th>
<th>Cyclopoids</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC, Y, T</td>
<td>94</td>
<td>70</td>
<td>91</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>M, Y</td>
<td>35</td>
<td>30</td>
<td>54</td>
<td>75</td>
<td>1</td>
</tr>
<tr>
<td>M, Y, T</td>
<td>48</td>
<td>8</td>
<td>8</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>M, Y</td>
<td>49</td>
<td>55</td>
<td>68</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>M, Y, T</td>
<td>14</td>
<td>17</td>
<td>16</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>M, Y</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M, Y</td>
<td>33</td>
<td>18</td>
<td>78</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>M, Y, T</td>
<td>1</td>
<td>5</td>
<td>78</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>M, Y</td>
<td>2</td>
<td>1</td>
<td>33</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>M, Y, T</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. Net efficiency\(^a\) of vertical and horizontal hauls of 335- and 80-µm mesh net for various taxa of microcrustacean zooplankton.

\(^a\)Net efficiency is expressed as the proportion (percent) of individuals caught per litre of water as compared with the Ruttner volume sampler.

\(^b\)Taxa are listed in order of decreasing size.

CM, Muruthawela; Y, Yodawewa; T, Tissawewa.
difference in Yodawewa is possibly due to the relatively high density of small cyclopoid copepods. The range of mean efficiencies is usually 30-70%. The catching efficiency of the 80-µm mesh net is lowered by the effects of clogging, and, in the 335-µm mesh net, a high proportion of the smaller species are lost through the larger openings. When comparing horizontal hauls, the effects of reservoir productivity on net efficiency are evident. In the less productive Muruthawela, the 80-µm mesh net is more efficient. Conversely, the 335-µm mesh net is more efficient in the productive Yodawewa.

Conclusions

Horizontal (80- and 335-µm mesh) net hauls are inefficient for collecting microcrustacean zooplankton and, hence, it is advised that this method not be used for estimating zooplankton densities. Both the 80- and 335-µm mesh vertical net hauls are usually more efficient; however, these methods still miss 50% of the population. In spite of this, after calibration, vertical net hauls are probably good enough for monitoring microcrustacean zooplankton populations. For population dynamics and production studies, however, a volume sampler is recommended.

Discussion of Sampling Methods

Introduction

This discussion is limited to two types of studies: those with the object of monitoring the microcrustacean zooplankton community as a whole and those detailed studies on the production or dynamics of selected microcrustacean zooplankton species populations. Monitoring the whole community can be useful when checking the stability of the zooplankton community or when following the annual or seasonal changes in the densities of the main taxa. Clearly, less accuracy is desired for monitoring than for population studies. For monitoring studies, the same type of sampling gear must be used at all times, samples can be taken at random or at fixed sampling sites, and samples must be collected at regular intervals. In most cases, a 1-month interval between collections is appropriate.

Published information on zooplankton production in the tropics is meagre (Dumont and Tundisi 1984; Dussart et al. 1984). The available information comes mainly from Lake Chad in Africa (e.g., Gras and Saint-Jean 1983), Lake George in Africa (Burgis 1974), and Lake Lanao in the Philippines (Lewis 1979). During the recent congress on tropical zooplankton in Sao Carlos, Brazil, more work on the secondary production of zooplankton in tropical water using a population-dynamics approach was strongly recommended (Dumont and Tundisi 1984). In this approach, besides the population density and population structure, it is necessary to measure the duration of egg and instar stages in relation to temperature and to assess instar body weights.

Sampling Strategies

Sampling accuracy is not only related to the type of sampling equipment used but is also largely affected by sampling design (for a review, see Prepas 1984). Zooplankton are usually not uniformly
distributed, either horizontally or vertically. Their distribution tends to be patchy, often with a strong vertical gradient of abundance that changes continuously over 24 h (diel vertical migration). Because of this contagious distribution, several samples should be taken to estimate the mean population density of zooplankton.

The number of samples to be collected at each sampling date should be carefully considered. Too few samples will render the sampling useless; too many samples will result in a precision higher than that desired and, consequently, will cost more labour and money. The method of calculating the approximate numbers of samples depends on the distribution pattern of the population to be studied. Often the zooplankton distribution is not approximately normal but approximates either a Poisson or a contagious distribution. For all those instances where the exact distribution is not known, Elliott (1977) proposed a method for estimating the number of samples required:

\[
N = \frac{S^2}{(D^2)(\bar{x}^2)}
\]

where \(N\) is the required number of samples, \(S^2\) is the variance (SD is standard deviation and \(S\bar{x}\) is standard error [\(S\bar{x} = SD/\sqrt{N}\)], \(\bar{x}\) is the mean population density, and \(D\) is the allowable size of the ratio of the standard error to the mean (\(S\bar{x}/\bar{x}\)). Depending on the degree of clumping of the zooplankton populations present, the absolute population densities, and the number of samples taken at each sampling date, an accuracy of 50-85% is usually possible. In a relatively large \((21 \text{ km}^2)\), well-mixed, temperate reservoir (Tjeukemeer, Netherlands), an accuracy greater than 80% can be reached. (Percent error is expressed as the coefficient of variation (SD/\(\bar{x}\) x 100) for \(\bar{x} > 10\) individuals/L when 20 samples are collected at 10 systematically distributed sampling stations (Nie et al. 1980; Nie and Vijverberg 1985)).

Prepas (1984) recognizes four main sampling designs: random, stratified, systematic, and composite. With random sampling, random sites are located at each sampling date. A random number table is often used. Occasionally, the environment to be sampled has many fairly homogeneous patches, but there may be large differences between individual patches. Under these circumstances, stratified random sampling can add considerable precision to the population estimate with a minimum of additional effort. Stratified sampling is also necessary for production and population-dynamics studies when different thermal strata are present.

Systematic samples are evenly spaced throughout a designated area, with the initial sampling point chosen randomly. Systematic sampling is more even than random sampling and easier to set up. It is often used for plankton samples when individual samples are pooled. Although information on spatial variation is lost in composite samples, pooling of samples is often necessary when it is infeasible to analyze individual samples. In routine sampling programs, composite sampling is often combined with random, stratified, or systematic sampling. During the 1st year of research, composite sampling should be avoided so that spatial variation can be
studied. In following years, samples should be pooled into one or a few composite samples (stratified sampling); this saves much time in analyzing (Nie et al. 1980; Vijverberg and Richter 1982).

Effects of Mesh Size on Filtering Capacity

Tropical microcrustacean zooplankton vary in size from 80 to 2000 µm, including different taxa and instar stages. The ability to escape collection varies among taxa and depends on the size, stage, shape, and behaviour of the organism. The smallest organisms (nauplii and early instar copepodites) may be filtered quantitatively with an 80-µm sieve; for larger organisms (e.g., cladocerans and advanced copepodite instars), a 120-µm mesh is usually more appropriate; a 250- to 350-µm mesh is usually appropriate for most adult copepods and cladocerans.

The smaller the mesh, the higher the proportion of small individuals retained on the net, but the sooner the net will clog. Thus, for small species present in high densities, small volumes of water should be filtered over fine-mesh gauze. For larger species present at low densities, large volumes of water should be filtered over coarse-mesh gauze.

With a net of a given mesh size, as towing speed increases, filtering capacity decreases (for a review, see Tonolli 1971). If the aperture size of the net is decreased from 363 to 76 µm, clogging and pressure within the net become severe. With the coarse net (363-µm mesh), the upper critical towing speed, where errors in metering the flow effect the estimated density from the catch, is around 1.0 m/s. With a 76-µm mesh net in unproductive waters, the maximum towing speed is about 0.8 m/s; this drops around 0.5 m/s in productive waters. In productive waters, both the speed and the length of the tow must be reduced.

When fine nets are absolutely necessary, the only alternative is to increase the effective filtering area of the net (i.e., increase the ratio of the area of the mouth of the net to the filtering surface from the normal 1:7 to 1:15 or greater). In most cases, however, and especially in productive waters, nets finer than 363-µm mesh should not be used (Tonolli 1971).

Subsampling Device

Because of the financial constraints of a research project, it is generally impossible to count an entire plankton sample. The distribution of microcrustacean individuals in a sample is often random, but counts of several subsamples should be performed to check whether the variance to mean ratio indicates random distribution. The estimate of the mean is usually accurate when each subsample contains 50-150 individuals (Prepas 1984).

Many devices have been used to subsample zooplankton samples before counting: the modified Folsom splitter (Longhurst and Seibert 1967), the whirling vessel of Kott (1953), and the George splitter (George et al. 1984) are the most accurate (for a review, see Van Gueelpen et al. 1982). The modified Folsom and George splitters divide a sample into 2 equal parts; the subsampler of Kott divides a sample into 10 equal parts.
Sampling Gear

Sampling gear for freshwater zooplankton has been reviewed by Bernardi (1984). Five types of equipment are used in freshwater studies: water bottle, trap-type volume sampler, tube sampler, towed plankton samplers (e.g., Clarke-Bumpus), and simple plankton nets. The first three types are all volume samplers. Because water bottles, although similar in many other aspects, show a lower catching efficiency than trap-type volume samplers, they are not discussed here. Even if a flowmeter is used inside the net, net catches should regularly be calibrated against a trap-type volume sampler. This calibration should be repeated several times a year because the seston concentration in the water will substantially affect efficiency.

Trap-Type Volume Samplers

Trap-type volume samplers are generally considered to be the most efficient zooplankton samplers currently available (Schindler 1969; Redfield 1984; Ni and Vijverberg 1985). They are especially recommended for production and population-dynamics studies (Bernardi 1984).

Tube Samplers

Tube samplers are useful in shallow reservoirs and littoral zones with macrophyte vegetation. The length of the tube corresponds to the maximum depth to be sampled. Two types are commonly used: a flexible tube and a stiff, Perspex tube. For long cores (>3 m), a rubber or plastic tube with thin, flexible walls is used. One of the most advanced tube samplers was developed by George and Owen (1978). This flexible tube sampler (diameter, 10 cm) provides a quick and efficient way of collecting zooplankton to a depth of around 10 m. According to George and Owen (1978), the efficiency of this tube sampler to that of most trap-type volume samplers. For short cores (<3 m), a Perspex tube can be used (Nie et al. 1980).

Towed Plankton Samplers

Several high-speed towed samplers have been designed, but most of these can only be operated from large boats. The Clarke-Bumpus (Bernardi 1984) is the only towed sampler that has been regularly used for sampling freshwater zooplankton. This sampler can be operated from a small boat and samples can be collected along vertical, horizontal, or sinusoidal hauls within a selected layer of water. The Clarke-Bumpus is essentially a plankton net fixed to a frame and connected to a flowmeter. The netting should have a mesh size greater than 80 µm; in productive reservoirs a mesh size of 150-200 µm is usually used (Duncan and Gulati 1981; Newrkl and Duncan 1984). The efficiency of the sampler has been tested against trap-type volume samplers. Schindler (1969) reports an efficiency of around 60% as compared with the Schindler trap; most other authors report higher efficiencies (e.g., Bernardi 1984).

The Clarke-Bumpus should be calibrated. When calibrated in a laboratory flume, where all the water from a metered source passes through the Clarke-Bumpus, the sampler accepts a relatively constant volume. The calibration for an individual sampler may vary from 4 to 5 L per revolution of the flowmeter between towing speeds of 0.25 and
Table 3. Recommendations for the choice of sampler to be used in assessment of microcrustacean zooplankton densities.

<table>
<thead>
<tr>
<th>Sampler type</th>
<th>Study purpose</th>
<th>Reservoir conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Deep</td>
</tr>
<tr>
<td>Trap-type volume sampler</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Tube sampler</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Clarke-Bumpus</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Simple net</td>
<td>++</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: ++, good; +, appropriate; -, poor.
*Production and population-dynamics studies.*
0.90 m/s. Below 40 revolutions/min, friction in the metering assembly makes the capacity appear higher; above 140 revolutions/min, back pressure reduces capacity. Each sampler should be initially calibrated in the laboratory and periodically checked in the field, where the sampler can be towed between fixed buoys separated by a known distance (Tonolli 1971).

Simple Nets

Nets are still the most common gear in the tropics for sampling zooplankton. If possible, a water flowmeter should be attached to the net. Nets may be practical when large quantities of water are to be filtered, i.e., in deep reservoirs (vertical hauls) or in lakes with low zooplankton densities. Shape and structure greatly affect the quantity of water that can pass through the mouth of a net (Unesco 1968). Plankton nets with a reducing cone placed forward of the mouth, such as the Hensen and Apstein nets, and with a filtration area at least three times larger than the area of the mouth are most efficient.

Recommendations

The choice of sampler depends on the purpose of the research and the conditions of the reservoir (Table 3). Generally, trap-type volume samplers are best for production and population-dynamics studies, and tube samplers, the Clarke-Bumpus sampler, or nets are preferred for monitoring studies. However, much depends on the local conditions of the reservoir. In deep, pelagic, unproductive waters, the Clarke-Bumpus sampler is preferred; simple nets are also appropriate. In contrast, in shallow, eutrophic reservoirs, trap-type volume samplers are best. Tube samplers are the only type that can be used efficiently in the littoral zone with macrophyte vegetation.

Acknowledgments

I thank Mr M. Arunachalam and Mr H.P. Koelewijn for their critical remarks on an earlier version of this paper. This work was supported by a research grant from the Office for International Cooperation of Leiden University, Leiden, Netherlands.

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