AN ANNOTATED BIBLIOGRAPHY OF FISHWAYS

Covering also Related Aspects of Fish Migration, Fish Protection and Water Utilization

by

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The literature of the fields indicated in the title is found in so many different periodicals and access to some of them is so difficult that an attempt towards completeness, particularly under war conditions, would be futile. However, an effort has been made to give to this bibliography a fairly comprehensive scope in the sense that it includes abstracts and titles of papers covering an entire group of interrelated subjects; and to make it as far as possible representative of all significant trends of recent progress in these fields attained mainly in western and northwestern Europe, as well as in this country. Accordingly, some older literature has been included, but that describing recent developments has been emphasized.

The last decade or two has brought considerable progress in the subjects in question, partly of a surprising nature. Energy dissipators for steep channels of high efficiency have been invented, tested, and developed by further study into simple, practical forms. Various mechanical devices for lifting fish, some to considerable heights, have been successfully introduced. Fish screens of various types have been invented and placed in use.

Paralleling these engineering developments is the progress made in the basic understanding of fish behavior. The effort of which the different migratory fishes are capable and the effort required to ascend the different kinds of fishways are beginning to be properly understood, thus making possible the first serious attempts to form rational rules for the design of fishways. The conditions under which turbines are passable without serious danger to the downstream migrants are also being determined, thus eliminating the use of fish screens in unnecessary cases.

Less conspicuous but hardly less important are recent studies tending to integrate the fishway problem with other problems of fish protection, and with other branches of water utilization. Only such integrated studies, as are increasingly pursued in Sweden, Switzerland, and this country, can reveal whether in an actual case the construction of fishways is economically warranted, or if special fish breeding or other measures should be substituted, or more frequently whether the measures should supplement each other. Such studies can reveal whether a proposed lake regulation will have a detrimental influence upon the fish, and how it may be counteracted. Only a combined study of the habits of the fish,
the hydrologic properties of the river and lake, and the changes which will be caused by the proposed hydraulic structure can bring about rational decisions on such problems. The progress in this combined study appears therefore to be a valuable step forward in the utilization of water.

This many-sided progress which here can be but incompletely indicated should warrant the present bibliography as an aid to further research, as well as to practical work. In order to make it more useful not only a general classification of the literature studied is attempted, but also at some points a few explanatory words are inserted between consecutive titles to combine the papers into smaller related groups. Several contradictions, some of them implicit, are pointed out, while other cross-references indicate coincident results of independent investigators. A few carefully selected illustrations are reproduced. Although they are only a very small part of the illustrative material in the papers abstracted, the writer hopes that they will substantially contribute to conveying some understanding of the hitherto little-noticed and often not easily accessible records of European fishway design and fish migration research.

This bibliography is a part of a study carried out by the Iowa Institute of Hydraulic Research for the Iowa State Conservation Commission, to develop the best forms of fishways for Iowa streams. The expenses of the study were largely contributed by the Conservation Commission. It is expected that a report on the experimental work of the project will be published in a later bulletin.

Mr. Edward Soucek, Assistant Hydraulic Engineer, Corps of Engineers, U. S. Army, Panama Canal, formerly Research Engineer at this Institute, in 1937-38 prepared abstracts of 33 American and English papers and a list of more than a hundred additional titles of American and European publications concerning fishways. The writer has freely drawn upon this material and wishes to express his appreciation of the thorough and able work done by Mr. Soucek preparatory to the present bibliography. For their helpful interest in this survey he is indebted to Prof. E. W. Lane, Mr. A. M. McLeod, Mr. M. L. Hutton, Mr. F. T. Schwob, and Mr. W. W. Aitken. He also wishes to extend his thanks to Mr. M. F. Thorne for collaboration in the final shaping of this paper.

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Iowa City
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I. Biology and Mechanics of Fish Migration

1. Houssay, "Puissance et Stabilité des Poissons" (Strength and stability of fish), Collection de Morphology Dynamique, Paris, 1912.

This is both a qualitative study of the locomotive methods used by fish and an attempt towards the quantitative characterization of the mechanical effort of which the different species of fish are capable. For the latter purpose the author uses an apparatus, inducing fish swimming in quiet water to lift different weights. The results of these experiments are shown by curves giving the rate of doing work as a function of the force exerted (weight lifted). The extensive results given by the author indicate, in agreement with other observations, the superior swimming ability of the rainbow trout compared with practically all other fresh-water fish. They seem to indicate on the other hand that some ocean fish are even superior to the rainbow trout.

2. Schmassmann, W., "Messungen über den Formwiderstand der Fische bei verschiedenen Wassergeschwindigkeiten und seine Berücksichtigung beim Bau der Fischpässe" (Measurements on the form resistance of fish at various water velocities and its place in the design of fishpasses), Schweizerische Fischereizeitung, Nos. 11 and 12, 1928.

The author measured the hydraulic resistance of dead fish and of living fish brought gradually to death during the procedure of measurement. The description of the apparatus conveys no exact idea of the procedure adopted (except that it was unnecessarily cruel). The representation of the results is not in a dimensionless form which alone is suitable for generalizations. The comparison of the measured resistances with the maximum force (effort) of which the different fish are capable (determined by Houssay in a research work in 1912; see Abstract No. 1) leads to velocity limits for the different species. How the author comes to the conclusion that this limit of 1.8 m. can be accepted for all species of fish remains incomprehensible to the present reviewer in spite of renewed study of the paper. In any case, in the light of G. Denil’s more recent research, the reviewer considers the results of Schmassmann to be incorrect, without being able to state whether the fault lies in the resistance measurements, in the reasoning and computations,
or in both. It would be possible to decide this by a dimensionless analysis of the data.

3. Schmassmann, W., "Einige allgemeine praktische und theoretische Gesichtspunkte zum Problem der Fischwanderungen" (A few general points, practical and theoretical, pertaining to the problem of fish migration), Reprint from Schweizerische Fischereizeitung No. 7, 11 pp., 1933.

The work of the Swiss-Badensic Expert Committee resulted, among other things, in securing a certain amount of data concerning the migration of summer-spawning fish. The data were gathered by counting the fish passing through the fishpass at Laufenburg, and by marking a great number of individual fish. The author agrees with Professor Steinmann and other experts that the results obtained to date are far from being sufficient for final conclusions. Yet, partly for practical use in juridical disputes, and partly to secure a "working hypothesis" for improvement of the methods for further observation, the author undertakes a study of available data and proves a very strong and characteristic variation of the migration of summer spawners with water temper-
nature. The curves reproduced are the main results obtained. The "daily average advance," however, gives no direct information concerning the swimming velocity of the fish, as it does not contain the velocity of the water faced, which is unknown and in the author's opinion probably much lower than the mean velocity of the river.

4. "Les causes de migration de l'anguille, jeune et adulte" (The causes of migration of the eel, young and adult), Bulletin Francaise de Pisciculture 5, pp. 374-376, 1933.

This is a report on an interesting biological study of Ejnar Sylvest, "Om betydningen af Kemotaxis og Rheotaxis for Claasaelens Vandring" (Naturens Verden, Copenhagen, December, 1931). The title may be translated as follows: "The influence of kemotaxis and rheotaxis on the migration of the eel of Clas."


The paper gives a short abstract of a lecture by Mr. le Danois, Director of the Office Scientifique et Technique des Peches Maritime, on "Bio-geographical Characteristics of Certain Sea-animals," delivered at the Oceanographical Institute of Paris, in which he gave a broad biological, paleobiological, and geographical review of the fish migration problem. The present publication is an abstract and a critical analysis of the contents of the lecture only in so far as the salmonides are concerned.

6. Denil, G., "La mécanique du poisson de rivière. Qualités nautiques du poisson; ses méthodes locomotrices; ses capacités; ses limites; resistances du fluide; effet de la vitesse, de la pente; résistance du seuil" (The mechanics of river fishes. Swimming properties of fishes; their methods of locomotion; their abilities and their limitations; the resistance of fluids; the influence of velocity and of slope; threshold resistance), Reprint from Annales des Travaux Publics de Belgique 1936, 1937, 1938, 395 pp.

The author's main purpose is to describe on one hand the nature and magnitude of the resistances encountered by migrating fish in the various types of fishpasses, and on the other hand, their ability to overcome such resistances. Thus he endeavors to secure a rational basis for fishway design. In connection with this research he describes and discusses incidentally a number of fishpass types, partly well-known and traditional, partly of the author's own invention. Some of these latter are well-established and thoroughly tested, others have been studied under laboratory conditions only, while
a few are suggestions without any direct experimental basis or confirmation. While the author deals at considerable length with some problems of biology and fluid mechanics which enter into the pursuit of his main study, the descriptions he gives of his fishpass designs are mostly very cursory and hardly sufficient for their reconstruction.¹

The following abstracts and quotations give some idea of the extensive studies of fish migration and fishpasses made by the author, as well as of the manifold hydraulic problems he brings in as illustrative analogies.

Introduction. The author presents his partly hypothetical views concerning fish. He believes that all species of river fish originally came from the ocean:

"The fresh waters succeed, for several reasons, in attracting quite a number of different species, some temporarily and periodically, either for the time of their growth or for that of their reproduction; while other species have settled in our fresh waters without ever returning to the oceans."

As to the nature of the migratory instinct he writes:

"Our most important migratory fish species appear to obey the law of so-called positive rheotropism,² i.e., they seem to be attracted only by the stream and by the effort the ascension requires. Some of our migrating fishes seem definitely to prefer the most rapid of the available tributaries, provided only that this does not overtax their swimming ability. It seems that they face a strong stream with pleasure. Only these fishes obeying the law of rheotropism are of interest in our investigation. The salmonides, characterized by their violent jumping efforts, are by no means the only fish which are positively rheotropic, in certain parts of the year making considerable efforts to travel upstream and to overcome rapids, or even waterfalls, whether natural or due to human interference. This positive rheotropism seems for some fishes, especially those of the carp family, to have no relation whatever with the functions of sex and reproduction."

Having expanded a little further his biological opinions, the author outlines the aims and program of his book:

"If we want to build rational, useful fishways which do not overtax the capacity of the migratory fishes, a thorough-going study is necessary. We must first understand the nautical properties of the fish; i.e., their specific methods of propulsion on one hand, the resistances they meet on the other.

¹ A few of the actual fishpasses built in the last 15 years after G. Denil's designs are described and discussed at some length by other authors, see particularly Lachadenede's Paper (No. 49).
² Rheotropism. The directive influence exerted on an organism by water currents.
The question of resistance is in itself not simple. Apart from the obvious resistance caused purely by velocity there is another resistance, which was until now open to controversy. This is the resistance due directly to the slope acting on any wholly or partially submerged body, on a ship as well as on a fish. I tried through direct experiments to decide this controversial point, and I think that my effort attained its aim. There is a third type of resistance which seems to have been quite unnoticed until now, which is met whenever a fish passes through an orifice or over an overfall weir. I shall call this additional resistance "threshold resistance." Having studied the resistances, it is necessary to study the power or ability of the different fishes to surmount these resistances, and I undertook this study directly on actual fishpasses."

The author adds to this outline the following remark:

"Our ships are obviously but unsatisfactory copies of the fish. Both are bodies freed from gravitation, encountering certain resistances in the fluid and in possession of certain propulsive apparatus to overcome these resistances. It may happen that my results concerning fish will prove to be of value in the theory of ship design as well."

Chapter I. Nautical Properties of the Spindle-shaped Fishes. The author divides all migrating fishes into "spindle-shaped fishes," consisting of the salmonides and the cyprinides (fishes of the carp family), and "very oblong" or "serpent-like" fishes, consisting of the eel and the lamprey.

In this chapter the author describes some of the spindle-shaped fishes and attempts to explain their anatomical and physiological properties in terms of the conditions under which they live.

Chapter II. Locomotion of the Spindle-shaped Fishes. The author discusses the mechanism of the different locomotive methods of these fishes. He studies first the swimming action against the stream. He shows on the basis of the work of Breder that the fish exercises propulsive forces on the water not only with its tail fin but with its whole body, and that the process of breathing is also an important element of the propulsive mechanism. He also uses the results of Breder to show that the fish needs for its swimming movements a considerably greater breadth than that of its body. The author discusses the difference between the characteristics of movements in rapid, strained swimming and in slow, comfortable swimming. Then he discusses on the basis of Roule's work the method of descent of these fishes. Finally he gives a description of the jumping efforts of salmon on the basis of his own observations and of trout on the basis of observations of Selys — Long Champs.

1 See Refs. No. 10, 11.
Chapter III. The Eel. Ascent, descent, and "reptation" (creeping-like movement) of the eel are described, together with the swimming movements of the lamprey.

Chapter IV. The Resistance Due to Velocity. The author being obviously unaware of recent developments in experimental fluid mechanics, considers Dubuut's experiments concerning the resistance of spheres, discs, etc., immersed in fluids, still to be the best available, though almost 150 years old. He also suggests that Dubuut was probably correct in assuming that the resistance of a body at rest in a current of velocity $V$ is different from the resistance of the same body moved with velocity $V$ in still water.

Accordingly, in his measurement of resistance, the author used a fixed body and flowing water, as this case comes very much nearer to the actual problem of the resistance met by a fish swimming through a rapids or through a fishpass than the case of still water and towed body. The author made measurements of the resistances of discs, spheres, and fish-like bodies of 3 different sizes, for velocities between $0.4m$ and $1.065m$. Unfortunately he does not represent the resistance coefficients as functions of Reynold's number, and therefore his results cannot be checked or generalized without further study. All resistance coefficients obtained by the author for fish-like bodies are, however, between 0.1 and 0.3, and he proposes to use the value 0.25 for all cases. Using this somewhat hypothetical value, he computes the resistances of fishes between $10^8m$ and $120^8m$ in length for relative velocities between $1m$ and $6m$ and gives the results of these computations in a table.

Under the plausible assumption that the force of which a fish is capable increases proportionally with its weight (Stringham) the author shows in his table that the velocity which can be faced by fishes is not independent of the size of the fish; on the contrary, it increases substantially with increasing size. He adds, however, that very large fish probably could not face the extremely high velocities which their swimming ability would permit them to overcome because of physiological disturbances which such high velocities might cause, especially in their respiratory organs.

Chapter V. Previous Attempts to Determine the Upper Limit of the Swimming Velocity of Fishes. The author gives a critical review of the earlier attempts to determine a velocity for different fishes. He deals with the publications of Roule, Jenkins, Vernon Bailey,
Stringham, and particularly of Kreitman, and shows certain shortcomings in the observations of the latter. He then discusses his own results published in 1909, the principle of which was to make fish observations only on fishpasses for which the velocity-distribution was thoroughly determined, and to observe which fishes passed and which failed to pass through these channels. The author points out that the fact that a fish’s negotiation of a fishpass obviously cannot in itself give any limiting value. Only when it is known that slightly smaller fish of the same species are unable to negotiate the same pass is an approximate limit found for the ability of the particular species.

In way of an introduction to his further research the author adds the following remarks:

“All of these computations — mine of almost 30 years ago, as well as those of Stringham and the more recent ones of Kreitman — are based on the assumption that the relative velocity between water and fish is the only source of resistance, which as far as I know has never been questioned until now. To make this assumption, however, is to dismiss without a test Dubuat’s thesis, according to which all bodies floating or submerged in flowing water are exposed to a force equal to the weight of the displaced fluid multiplied by the slope, in addition to the resisting force corresponding to the relative velocity between the body and the water.”

The author shows with convincing numerical examples that it is of decisive importance in rational fishpass design to learn whether the usual assumption is well founded, or whether, on the contrary, there is an element of truth in Dubuat’s contention.

Chapter VI. The Controversy Concerning the Influence of Slope. The author takes as his starting point the well-known and hardly disputable fact that a loaded ship drifting downstream on a river always has a higher velocity than the surrounding water when it has attained uniform motion. He quotes from Dubuat’s famous “Principes d’hydraulique et d’hydrodynamique” (Paris 1816) the passages in which an explanation of this phenomenon is attempted. The author himself does not consider Dubuat’s explanation to be satisfactory. On the other hand, he shows convincingly that the refutation of Dubuat’s opinion by Bérard is inadequate both on experimental and theoretical grounds. (Bérard tried to prove that the above-mentioned phenomenon is a mere delusion caused by the non-uniform velocity distribution in a cross-section.) Finally the author quotes and discusses Flamant’s views on this question as stated in his fundamental work “Hydraulique” (1909).
Flamant recognized the correctness of the previously mentioned observation. He contended, however, that it was merely an effect of turbulence pulsations and that on water with laminar flow nothing of the kind would occur. The author considers Flamant's attempt at explanation not only unproved but also implausible. He shows the necessity of a thorough quantitative experimental investigation.

Chapter VII. Experimental Demonstration of the Influence of the Slope upon Floating Bodies (Ships, etc.). The author considers his steep channels fitted with highly effective energy dissipators particularly apt for the experiment in question as they make it possible to vary the slope within wide limits while keeping the velocities practically constant.

![Dynamic Influence of the Slope upon a Ship-like (or a Fish-like) Body](http://ir.uiowa.edu/uisie/23)
The author fixed his ship model on a rotating disk (a hydrodynamic balance, as he called it) and measured the turning moment acting upon this balance. He assumes that this is exactly proportional to the longitudinal force acting upon the ship model, an assumption obviously implying an arbitrary hypothesis as to the line in which the force perpendicular to the slope is acting.

The figure shows some of the results obtained by the author. The figure indicates that in addition to $F_0$, a force even greater than $G \sin \alpha$ acts longitudinally upon the body. One can therefore infer that the buoyancy does not act vertically, but must be nearly normal to the water surface.

Chapter VIII. Action of the Slope Upon the Fish. The Principle of Archimedes Extended to a Sloping Stream of Water. The Additional Immersion of Floating Bodies Due to the Slope. Surface Slope as a Factor of Erosion. The author repeats his experiments, reported in the previous chapter concerning ships, for fish-like bodies and finds that the formula

$$0.25 \frac{V^2}{g} + G \sin \alpha = F_0 + G \sin \alpha$$

approximates roughly the total resistance. He attempts, also, to give a theoretical explanation of this result, independent from the conception of turbulence.

Returning to the floating body (ship), the author tries to show by theoretical considerations that the immersion for a flow with slope $\alpha$ is greater than that for a horizontal water surface, the ship displacing $\frac{1}{\cos \alpha}$ times more on a steep surface than on a horizontal one. This supplementary immersion results in a higher velocity resistance, in the author's opinion accounting for the difference between the measured value of the longitudinal force and the value $F_0 + G \sin \alpha$.

The rest of the chapter deals with two hydrological problems. It is the author's belief that rivers with a steep water surface erode their beds much more rapidly and remove much heavier stones from their beds than rivers of lesser slope but of the same "bottom" velocity. The author believes that in a similar way the "momentary slope" of the surface of waves has a strong influence upon the sand and gravel movements on beaches. These statements are based only upon vague theoretical considerations and qualitative visual observations of the author, and are not substantiated by any measurements.
Chapter IX. The Fish Which Use the Fishpasses. This chapter deals mainly with the different conditions under which the migrations of the various fish species take place, and the different "motives" which urge them to their migratory efforts. He deals particularly with the influence of water temperature upon the migration of the summer spawners, and brings in some observations of his own which confirm the well-known importance of the water temperature, but which do not allow quantitative generalizations. The author found very large differences between migratory accomplishments of individual fish of the same species and considers the conception of tropism or of automatism to be in itself by no means sufficient for a conclusive explanation.

Chapter X. The Swimming Abilities of Salmon and Trout. The author returns here to his investigations in the earlier chapters and attempts a quantitative determination of the efforts of which the different species of fish are capable.

First he makes an analysis of observed jumps of salmon and trout and comes to the conclusion that both are capable of developing for an instant a force \( F \), considerably greater than their own weight \( G \). For the salmon he finds \( F \) is about 1.2 \( G \), for the trout, 1.4 \( G \).

He then discusses the strained swimming of salmon and trout through fishpasses. From his velocity measurements of 1908 at the Caméré-type fishpass at Angleur, and at its successor which was the first fishpass designed according to Denil's principles, the author is able on the basis of the results of Chapter VIII to compute the values of total resistances opposing the passage of fish through these different channels. Since ample evidence is available from the author's and others' observations concerning the failure of the Caméré pass in question, the partial success of the first Denil pass, and the almost complete success of the second Denil pass (being a slightly improved form of the first), it is possible to make a fairly good determination of the limit of effort of which salmon and trout are capable. The result shows that salmon and trout are capable of exerting very considerable forces amounting to 0.6 \( G \) and 0.7 \( G \)

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1 See also Refs. 17, 18.
2 "The power or fact of movement (1) independently of external stimuli as the beating of the heart; or (2) directly from the effect of external stimuli but independently of conscious control." (Webster's New International Dictionary)
respectively. This means that they are capable of exercising half as large a force for a period of about 50 to 60 seconds as they can develop instantaneously.

Chapter XI. The Swimming Abilities of the Cyprinides. The author gives a few data concerning four of his more recent fishpasses, two of them almost identical in design.

On the basis of velocity measurements and of fish observations made at these fishpasses, the author shows, in complete analogy with the methods used in Chapter X, that the cyprinides are able to develop a force of 0.5 G for about 50 to 60 seconds. For the computation of their instantaneous effort no direct observations are available. By comparison to the salmonidés, he assumes it to be about 2 x 0.5 G, i.e., G.

At the end of the chapter the author deals with the proper arrangement of the downstream end of fishpasses and makes an interesting suggestion along this line.

Chapter XII. The Maximum Velocity of the Fish and its Reduction Due to the Influence of the Slope; Reduction in Case of Long Continued Effort. The author gives practical conclusions resulting
from the limits found in Chapter IX and X in the form of tables and graphs. He adds, on a more hypothetical basis, a graph making it possible to allow for a longer passage between two resting pools than that corresponding to a travel of 60 seconds.

Chapter XIII. Passage Through a Submerged Orifice. The author attempts to show that the threshold resistance met by a fish passing through the orifice in a pool-orifice type of fishpass is analogous to the slope resistance in a steep channel, the former resulting from the difference in the static pressures to which the two halves of the fish are subjected in consequence of the difference in levels of two consecutive pools. According to the author's experiments and computations this additional resistance is about three times the velocity resistance computed by the formula $\frac{0.25 V^2 F}{2g}$.

This result, combined with the results of the Chapters X and XI concerning the maximum force which the different fish are able to exercise for an instant, leads the author to the following practical rule:

The head (difference in levels) between two consecutive pools must always be chosen proportional to the length of the smallest fish for which the pass is intended, the coefficient of proportionality being 0.55 for cyprinides (carp family), 0.66 for salmon, and 0.77 for trout.

Some further practical suggestions concerning rational designs of pool-orifice fishpasses complete the chapter.

Chapter XIV. The Overfall-Jet. The author studies pool-overfall fishpasses, the different types of overfall-jet fishpasses (free jet, overfall ending with hydraulic jump, and overfall with standing wave), their hydraulic properties, and the movement of fish in them. In case a pool-overfall fishpass should be chosen at all, the author recommends that the pool dimensions be made so that formation of a standing wave is avoided, and gives definite instructions to meet this purpose.

Chapter XV. The Passage of Fish Through Closed Conduits and Through Converging Tubes. A Highly Effective Energy Dissipator for Closed Conduits. Two Solutions for the Fishpass Problem in Case of Very Large Headwater Fluctuations.

A number of original suggestions, most of them not yet tested in practice, are given:
An improved form of the pool and submerged-orifice pass is proposed in which the orifice is replaced by a convergent tube of special shape, which in the author's opinion should very substantially reduce the "threshold resistance."

The author then makes a suggestion concerning the possibility of adapting his principle of steep-channel design with energy dissipator to the needs of open channels with widely fluctuating water depth. He also discusses the question of building closed conduits with rectangular cross-sections having a similar high rate of energy dissipation. Finally he shows how to combine ordinary Denil fishpasses with special conduits of one or the other kind mentioned to deal with very large headwater fluctuations.

The chapter contains a digression into the design of ship locks and touches upon some fundamental problems of fluid mechanics.

Chapter XIV. Concluding Remarks. Here the author returns to the central problem of the work: the question of how much effort the different fish are capable of exerting. He makes further arguments in favor of his basic assumption that for one given species the force which can be produced is proportional to the weight of the fish and not, as some physiologists assume, to the cross-section of the "main motor muscles."

He discusses some failures of fishpasses imitating the Denil design in an unscientific way, particularly in applying too steep a slope.


This is a review and critical appraisal of G. Denil's book (Abs. No. 6). The reviewer calls attention to the possibility of comparing G. Denil's results concerning the effort of which the various fish are capable with Houssay's results (Abs. No. 1). He finds the agreement, though apparently very rough, significant because of the complete independence of both researches from each other and the basic difference in their methods.

The reviewer considers Denil's contributions to be significant for four different, though overlapping, fields of work:

1 Two or more abstracted or listed papers having a particularly close connection are given a common reference number, the papers being identified by indices, either as 6, 6a, or 14a, 14b.
But he thinks that even more important than the results contributed directly by Denil's work are the results which are likely to be achieved due to the stimulus it may give to these fields of research and practical work.

For papers concerning the locomotion of fishes, particularly the dynamic aspects, see the following publications also.

12. Steinmann, "Wie es der Fisch anstellt um sich von dem Weggeschwemmtwerden zu schützen" (How the fish protects itself from being swept away by a current), Schweizerische Fischereizeitung, 1928.
13. Kreitman, "Contribution à l'étude des caracteristiques des passes à poisson: La vitesse de nage des poissons" (Contribution to the study of the characteristics of fishpasses: the swimming velocity of fishes), Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie, 1931.

For investigations based essentially upon tagging and counting of fish for purposes of studying their migratory habits and locomotive efficiency (in some cases also for purposes of practical fishpass testing), see the following publications.

14a. Koch, "Aufstiegskontrollen an Fischpässen" (Checking upon the negotiation of fishpasses by upstream migrants), Deutsche Wasserwirtschaft, 1930.
14b. Koch, "Fischmarkierung am Badischen Rhein und Neckar" (Tagging the fish in the Badenese reaches of the Rhine and Neckar rivers), Badische Fischereizeitung, 1932.
15a. Steinmann, "Ueber den Fischaufstieg im Rhein und in der Aare auf Grund von Fischpasskontrollen im Jahre 1934" (On the upstream fish
migration in the Rhine and in the Aare on the basis of fishpass control experiments in 1934), Schweizerische Fischereizeitung, 1935.

15b. Steinmann, "Von der Notwendigkeit der Fishwanderungen für das Gedeihen der Bestände und von der Leistung gut konstruierter Fischpässe" (The necessity of protecting fish migration and the effectiveness of well-designed fishpasses).

16. Alm, G., "Laxmärknings Betydelse for Kennedomen om Laxens Biologi" (The importance of tagging salmon in the study of its biology), Svensk Fiskeritidskrift, 1925.

17. Denil, G., "Le Contrôle des échelles à poissons du barrage de Monsin et celui de quelques échelles apparentées" (Checking upon the effectiveness of the fishpasses at the Monsin weir and similar fishpasses), Publications de la Société Centrale pour la Protection de la Pêche Fluviale en Belgique, Bruxelles, 1935.

18. Denil, G., "Le barrage d'Angleur et le contrôle de ses échelles à poissons" (The dam at Angleur and the testing of its fishpasses), Publications de la Société Centrale pour la Protection de la Pêche Fluviale, Bruxelles, 1936.

Facts and discussions on fish migration are found in the following biological publications.


22. Plehn, M., "Die Fische des Meeres und der Binnengewässer" (Ocean fish and fresh-water fish), München, 1908.

23. Walter, E., "Der Flussaal" (The river eel), 1910.


Also compare with much of the literature discussed in other sections of the bibliography, particularly abstracts No. 45, 53, 54a, 125a, 134, 139.
II. Fishways

A. Fishways Proper


This bulletin deals with the laws pertaining to fishways for dams passed by Congress and by the New York State Legislature. In addition, detailed proposals as to design of fishpasses are made. The fishway recommended is of the "improved Cail type" exemplified by a fishpass in timber and by one adapted to a masonry dam, the latter being a design of H. von Bayer of the U. S. Bureau of Fisheries.

The Bulletin stresses the importance of a strong, well-protected structure and of a design which does not include any regulating gates or other devices which would necessitate the services of an attendant.


The report rightly stresses the importance of studying each individual case of fishpass design separately, taking into account the particular topographic features of the site, the species of fish, etc.

Some other views expressed in the report cannot, however, be accepted in the light of more recent research and experience. Among others, the author's view that some 20 or 30 feet is the upper limit of total height for any salmon ladder is unacceptable for several reasons, the simplest being that the designer practically always has an opportunity to divide the total height by resting pools sufficiently large to provide complete rest for the migrants.


"The great salmon fishing industry of the Northwest makes the fishway an important consideration for the engineer who is planning hydroelectric developments in that region. Substantial progress has been made in salmon fishway design for overcoming high obstructions in the streams of Oregon and Washington, but the problems presented in the Klamath River (in California) in a river supporting a commercial run of salmon have not been previously attacked. Some interesting notes on the problem are given by Mr. H. W. Crozier, Electrical Engineer, Sanderson and Porter, in the August 1 issue of the Journal..."
of Electricity and Western Industry, from which the matter following is
abstracted.

"As a salmon is a large active fish, several feet long and sometimes attaining
the weight of 90 lbs., necessarily fishways for his accommodation must be
of substantial size. One type of fishway that has been used consists of a deep
flume 6 ft. wide divided into 6 ft. boxes by partitions which have a 2 ft. notch
arranged for spilling water from each box to the next. From 8 to 10 second-
foot of water is required. A better way, however, is to construct the fishway
as a series of pools, water spilling from one pool to the next; as thereby, when
the physical conditions permit, pools of large dimensions may be obtained with
moderate expense. The secret of success with fishways for salmon is to make
them of ample size with plenty of water, and to provide frequent extra large
pools for resting purposes."

The article also includes photographs of two salmon fishways and
some discussion of the salmon problem in general.

30. "Fish Ladder for Columbia River," Electrical World, Vol. 98, p. 775,
Oct. 31, 1931.

"Each ladder has adjustable stop-log barriers, is of rock and concrete, and
is 20 ft. wide with a slope up and downstream of 1:10. Since the maximum
difference in water levels at the dam will be over 50 ft., the ladders are each
500 ft. long. One is on the east and one on the west bank of the river, each
along the downstream side of a concrete abutment section with openings
through the abutment at various levels to allow a flow of water into the fish-
way and to permit the upstream passage of fish into the reservoir."

This article describes the fish ladder of the Rock Island hydro-
electric plant of the Puget Sound Power and Light Company on
the Columbia River near Wenatchee, Washington. There are no
drawings. A photograph which appears shows nothing in addition
to the description quoted.


A short discussion of the fishpass problems is given which is based
mainly upon the recommendations of the New York State Conserva-
tion Commission.


A classification of the familiar older types of fishpasses is given
and the following general remarks are added:

"The ladders may be protected by a grating but must not be entirely cov-
ered, as the fish will not pass a dark compartment. The habit of fish is to pro-
ceed up the river until halted by an obstruction, and then to nose their way
from side to side, searching for a passage, always facing upstream. Therefore
the entrance to the lower end of the fish ladder should be flush with the toe
of the dam, as the fish will not turn downstream to enter it. A slope of the
trough of 4 or 5 horizontal to 1 vertical is usual. The required size and type of fish ladder depends upon the type of fish which are to use it. Such details are usually prescribed by the State authorities."


An attempt is made to classify the older, familiar types of fishways. The author gives the following general suggestions:

"The installation of a fishway requires careful study and planning. If the pond level varies somewhat, the upper section of the fishway must be made adjustable, with an arrangement either of gates or stop boards to allow for different water levels.

"The entrance to the lower end of the spillway should be at the foot of the dam, to accord with the locus of the greatest flow of water. This may require a return angle (in plan) of the fishway. Damage by floods may be minimized by a protected location, by suitable concrete construction, or by having a part of the fishway removable when not in use."


"In almost every state fishways are required by law in any dam constructed on natural waterways. These fishways must be so arranged as to permit the free passage of fish up the stream.

"The purpose of these fishways is to afford a gradual incline through which a continuous stream of water of comparatively low velocity shall flow and against which the fish may readily swim. Both the inlet and outlet should be below low-water and the outlet should be in such a position that the fish, when they ascend the stream and reach the dam, in passing from one side to the other in searching for a passage, are naturally led to the point where the flowing water is encountered. The slope of these fishways should not be steeper than one vertical to four horizontal, and the water should be so deflected that the velocity will be reduced as much as possible. A fishway should be entirely automatic and free from all regulating devices. It is usually desirable for the openings in the bulkheads or baffles to increase progressively from the lower to the upper one in order to insure that the passage of the fishway shall be full of water. The fishway should be so covered as to prevent interference, but must be light or it will not be used by the fish."


The author gives a description of the pool type fishpass and makes some suggestions for its practical design. Details of two fishways and photographs of a few others are given.


A description is given, accompanied by a plan and an elevation of the fishway which has been designed by L. L. Wheeler.

Adjacent to the pump house is a Cail type fishway, the river being used by alewives. The fishway has proved very satisfactory.

This article describes a water supply developed for a steam power plant in Massachusetts. A plan, elevation, and two sections of the fishway at the plant are shown.


"In Fig. 2 the details of the fishway are given. This consists of a four-direction ladder made up of concrete pockets which hold pools of water. Small openings at the bottom of each pocket ensure a free flow of water and a possible passageway for the fish."

No other comment on the fishway is given in this article but there is a well-dimensioned sketch of the fishway, which changes direction in plan four times in order to increase the length of travel and still keep it within the Ambursen-type dam.


"A height of 50 ft. had long been accepted in the Northwest as the limit to which salmon would climb up a fish ladder on the way to the spawning grounds. Since the Baker River Dam is 263 ft. high, something had to be done or an industry important to that section would be destroyed.

"A scheme of trapping each step in a fish ladder against the return of the fish downstream was devised. The theory is that when the fish gets tired or discouraged it will not be carried downstream by the current but is trapped at the point where it happens to be until it is ready to proceed. The most important element in the scheme is the curved finger-like rods which are placed at each 2 ft. drop of the ladder, constituting a guard or trap which prevents a tired fish from being carried downstream. These rods do not form a barrier to movements upstream because the salmon invariably leap over them."

The scheme of trapping fish in the ladder against downward drift is to be noted. The ladder and elevator at the Baker River dam are "in series" so that the fish do not ascend the 260 ft. by ladder (See Abs. No. 39d).


"The prevalent opinion that a salmon would refuse to climb a fish ladder where the difference in elevation was more than about 50 ft. has been overthrown by the proved willingness of sockeyes on their journey upstream to the breeding places to climb and be assisted over the 265 ft. dam of the Puget Sound Power and Light Company on the Baker River in Dkagit County, Washington. Later, when the young fish are hatched and ready to descend the stream, the little swimmers, six or seven inches, joyously leap from crest to base and take no harm from their adventure."
Three photographs of the Baker River development accompany the paragraph quoted.


This is another article on the Baker River fishway and elevator in which favorable comment is made on the work done there. The article contains no information in addition to that already covered.


In this article the operation of the elevator at the Baker River dam is described in some detail, as is also the method of trapping each step of the fishway to prevent the current from carrying the salmon downstream when it becomes tired. (See Abs. No. 39a). It is stated that the "elevator is used . . . . to lift the fish the major portion of the height." The downstream passage of small salmon over the crest of the dam — a drop of 200 ft. — is also described.


A committee report dealing with committee accomplishments, activities, inspections, legislative matters, etc. The article contains no technical information and no descriptions of fishways. The Baker River fishway and the experiments with electrical screens receive favorable comment.


"The International Pacific Salmon Investigation Federation, which is said to include the 'leading fisheries officials of the United States, Dominion of Canada, British Columbia, Washington, Oregon, California, and Alaska,' at its annual meeting in Seattle, Dec. 2, 1926, adopted a resolution condemning 'propaganda based on the partial success of an experimental fishway at the Baker River dam'.

"The Resolution reads:

'Whereas, a constant and nation-wide propaganda has been maintained in newspapers, engineering and technical magazines conveying the impression, based on the partial success of an experimental fishway at the Baker River dam near Concrete, Wash., that a complete solution has been reached of the problem of safeguarding salmon runs jeopardized by the construction of dams; and

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AN ANNOTATED BIBLIOGRAPHY OF FISHWAYS

'Whereas, in the opinion of this federation no solution of this problem has yet been reached that can properly be considered as of general application, and
'Whereas, much of the work of the Baker River dam so far has been experimental and the results there are not yet conclusive,
'Therefore, be it resolved, that the International Pacific Salmon Investigation Federation at this meeting of Dec. 2, 1926, strongly disapproves the propaganda above mentioned as being unwarranted and misleading; and
'Be it further resolved, that copies of this resolution be presented to the newspapers and periodicals and to such officials and others who may be interested.'

An editorial note accompanying this article points out that the work accomplished "... is certainly notable progress. It is to be hoped that a broad view of the whole problem will be taken by all concerned so that the work yet to be done may have full co-operation of all interests." While this article contains no technical information, it is included to illustrate the diversity of opinion which exists regarding the fishways of Baker River dam, favorably mentioned in abstracts No. 39a, b, c, d, e.


This is a short abstract of the author's report concerning his wide experience with fishways during his activity with the United States Bureau of Fisheries. The paper deals only with variants of pool-type fishpasses. The following remark of the author should be noted:

"A small opening on the floor and connecting the pools is desirable for draining and cleaning purposes, though it should be removed from the general line of travel so as not to form cross-currents or disturb the fish if they desire to rest on their upward journey."

For similar reasons the author deems the type of orifice disposition known as the Cail type unsuitable for fishpasses with comparatively small pools. As to the general disposition of the pass, its entrance and exit, the author gives the following suggestions:

"Changes in the direction of the fishway should be kept to a minimum, but where made it will generally be of advantage to have pools with more depth and area. Comments that a fishway must have ample light may be correct, though it is known that salmon and trout have used fishways that were under the back face of a dam where light penetration was limited.
"Location of a fishway is important, especially its entrance. This should be at a point in or near the immediate vicinity of the line of travel of the fish, or where they usually congregate, and also be close to the base of the dam, yet avoiding too much of the overpour from the dam. At times the lower pools of the fishway may be submerged but some portion of the fishway should
be readily accessible to the fish... More than one entrance to a fishway may be necessary.

"The exit of the fishway into the waters above the dam should preferably be where the velocity of the water is low, and should be removed, if possible, from outlets or diversions. It should be protected from moving debris so that the water flow through the fishway will not be interrupted and the fish not hindered in leaving the fishway."


"... the ladder consists of a series of pools with ascending water levels connected by submerged orifices. At intervals longer and deeper 'resting' pools are provided. Each orifice at Tongland is controlled by a sluice valve; at Earlstoun and Carsfad similar ladders are being constructed, but the separate sluice valves have been found unnecessary. A further improvement is a means whereby at suitable seasons and for short periods a considerably increased flow — to represent a freshet — can be sent down the ladders as an additional inducement to the fish to ascend... Fishery interests, too, have suggested that numerous rocks should be placed in the resting pools for the fish to shelter under. The ladder at Carsfad has thirty-six steps and three large resting pools. As the level in the reservoir will vary to the extent of 4 ft. or so under normal operation and up to 8 ft. exceptionally, the first and third pools of the fish ladder are both connected by passages controlled by sluice gates to the reservoir. The sluices are controlled automatically by the water level, so that if the upper one is open the lower one is closed, and vice versa."

Elsewhere in the article it is stated that the maximum drop from pool to pool is two feet. It is to be noted that these ladders of the submerged orifice type are for the passage of salmon — in contrast with the "overflow" type of ladder commonly used for salmon in the United States.


"... to enable them to reach the foot of the ladder, water will be necessary in the river channel between the dam and the power station and this will normally be provided by the flow down the ladder. It can, however, be supplemented by water which is discharged from a 24" pipe with an 18" disperser, installed in the arch dam adjacent to the 60" needle valve described in the first part of this article. The ladder itself may be likened to a broken stairway and consists of flights of stepped chambers, which are interrupted by landings in the form of large resting pools. There are five flights and four resting pools in the total rise of about 70 ft., the number of steps being thirty-six. Connection from chamber to chamber is generally by means of submerged orifices, the size of which can be altered by means of hand sluices to suit varying flows. These sluices are operated in groups of four or five by shafting and gearing. The normal rise from chamber to chamber is about 2 ft. and the sluices are
adjusted so that most of the water flows through the submerged orifices and only a small amount passes over the cross walls."

This article describes the Tongland dam of the power development which includes the Earlstoun and Carsfad dams described in Abs. No. 41. Special arrangements are made at this dam, as in the other two, for dealing with large fluctuations in headwater level. At Tongland three pools, the first, third, and fifth, may be connected directly to headwater. Detail drawings of the ladder are given.


"... the elevator and the ladder are both located at one abutment of the dam. The ladder is Z-shaped in plan and consists of two parallel series of basins 6.2 by 6.2 ft., 6 ft. deep, differing in elevation by 6.7 inches. It is shown in Fig. 4. A fish entering from tailwater at the lower end of the ladder will ascend through the right-hand series of basins in a general downstream direction up to the mid-height of the structure, where its course will be deflected into the left-hand series of basins and will be reversed to a general upstream direction and over the crest of the dam into headwater. The transverse baffles of the basins have a square notch at the top and a square hole near the bottom, both off center. Both notches and holes are not in line but staggered, thus favoring the formation of still-water nooks where the weary fish may rest. The basins are so designed that the velocity of flow will not exceed 5.9 ft. per second, no matter what the water level above the dam may be. The fish ladder cost nearly $65,000."

A small figure shows the Z-shaped general disposition of the fishway. The article calls attention to the "much cheaper" arrangement for the passage of salmon than that used at Bonneville. "... the fish ladder and fish elevator for the Kembs Dam, which is about 50 ft. high, cost 200,000 German Reichsmarks in all, or not quite $81,000." The elevator which can be used alternatively to the fish ladder is also described.

43b. Meyer-Peter and Schmassmann, "Zur Konstruktion von Fischpässen nach dem Beckensystem" (Contributions to the design of pool fishpasses), Schweizerischer Wasserwirtschaftsverband, Schrift Nr. 19, Zürich, 1932.

This is a detailed and well-illustrated report on the extensive laboratory experiments (Zürich) which were made preparatory to the design of the Kembs fishpass, (See Abs. 43a). As Table 1 of the original publication shows, the elaborate disposition of the upper and lower notches relative to each other gives some advan-
Horizontal Section Through the Overflow Notches

Horizontal Section Through the Lower Orifices

Streamfield in the Model of the Kembs Fishpass

Crosswalls 12, 16, 20
Crosswalls 13, 17
Crosswalls 14, 18
Crosswalls 15, 19

Proposed Crosswalls

Abstract No. 43b

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tages (which however do not appear to be very significant compared on a percentage basis with some of the simpler arrangements). A more important feature of the Zürich design is that the submerged orifices in the 12 uppermost baffles are larger than the rest. The experiments have shown that this simple device (which is somewhat analogous to the "Cail type") acts as a reliable automatic "flow regulator" for widely variable headwater levels.

At the end of the paper the authors compare their pool fishpass with the simplified Denil fishpass as suggested by Lachadenede (See Abs. No. 51). This comparison does not appear to the present writer to be convincing, because of the great difference in the shape and size of the free cross-sections.

44a. Office of the District Engineer, U. S. Engineer Office, Bonneville, Oregon, "Fish Protection at Bonneville Dam," Mimeographed, 7 pp., 5 figs. on separate sheets.

This is a short authoritative description of the fish protective devices at Bonneville, which are probably the largest, most comprehensive, and most costly ever undertaken at any dam or power station. The devices include two fish ladders, one by-pass, three pairs of fish lifts, and three elaborate collecting systems for attracting the fish and directing them to the fish ladders and lifts. For downstream migrants there are three special by-passes in addition to the fish ladders, as well as the ice sluices which will be available for the passage of downstream migrants when not needed for ice. Two quotations may give an idea of some special features of the fishways:

"Peculiarities of the Bonneville project call for modifications in the conventional fishladder. Most important of these is the variation of approximately forty feet in water level below the dam. In this way the entrance at high water would be removed from its original location by a distance of several hundred feet. To compensate for this situation the side walls of the ladders are extended to high water level and an auxiliary water supply is added. The high side walls will maintain the entrance at the same point at all river stages (except extreme floods when the fishways will be out of operation); the auxiliary water supply provides an additional quantity of water and thus maintains a noticeable velocity in the deep channel over the submerged portion of the ladder. This auxiliary water is added through a series of diffusing chambers by which it enters the channel at a velocity much lower than the longitudinal flow in the channel; the fish following against the prevailing direction of flow, thus are not attracted to the diffusing chambers but continue up the ladder."

"The collecting system designed for use in connection with the fishways at Bonneville involves features new to fishway design. These features are intended to increase the attractiveness of the fishways entrance and thus to

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aid the fish in finding them . . . The collecting systems have been designed to increase the attractiveness of the entrances first by providing multiple entrances at various places and of various types; second by providing a greatly increased quantity of water to be discharged through these entrances."

For a shorter description of these fishpasses and fish sluices see the article which follows.


Compare with Abs. No. 139 and Ref. No. 139a, in which these fishways are discussed as part of the entire Columbia River fish protection problem.

45. Otterstrøm, C. V., "Fisketrapper" (Fish ladders), Reprint from Ferskvandfiskeribladet 34, Nos. 2-3, 39 pp., 1936.

This paper is a critical survey of the fishpass problem based on the author's first-hand knowledge of the fishpasses in Denmark and on his study tour in Switzerland and southern Germany. The Belgian and French fishpass systems (steep channels with special types of roughness) are hardly touched upon, while the various shapes of the pool-and-jet fishpass are described in some detail. A valuable feature of this study is that some interesting failures are described and an attempt is made to explain their causes.

Note
"a" and "b" are baskets filled with wood-shavings or heather

Danish Young Eel Pass

Abstract No. 45
The most interesting part of the paper is that which deals with the "young-eel" passes, and a good description is given of the Danish "young-eel" pass (Löfting), a device of great simplicity and of excellent efficiency if properly constructed and maintained.

Kreitman, L., "Étude hydraulique des passes à poissons" (Hydraulic study of fishpasses), Bulletin Française de Pisciculture 6, pp. 122-130 with 9 large plates, 1933.

The author reports on his experiments made in collaboration with the Société Hydrotechnique de France in their laboratory at Beaufert near Grenoble for the purpose of studying velocity conditions in pool-and-jet fishpasses. (Originally, Denil passes and their derivatives were also on the program of research but they had to be discarded for the time being.)

In the first part of the study a variety of pool-and-jet passes of more or less traditional types were studied. The orifices were located

a. Axially.

b. Near the side walls in a straight line.

c. Near the side walls, disposed in a zigzag line.

d. Near the side walls, two consecutive orifices on the same side, and each pair on alternate sides.

The author could not find, however, any considerable reduction of the velocities as the result of any of these particular designs. Neither could he find any essential justification for the design advocated by the Commission Suisse de Passe à Poisson (a type of the Kembs fishpass) which may be considered as a combination or a "halfway solution" between (a) and (d).

In the second part of the experiments the author therefore investigated the energy dissipation resulting from a replacement of the orifices by short tubes fitted with oblique obstacles of the shape indicated in the figure.

The energy dissipation caused by such tubes is fairly considerable, particularly if the obstacles are spaced at a distance which about corresponds to the depth of the free opening, as may be seen from the diagram reproduced.

The author concludes his paper with the following remarks:

"This design is interesting, and it may be worth while to try it in actual practice. It may be particularly suitable for a location where an existing fishpass on a dam becomes unsuitable owing to an increased maximum head-water level. In such a case, this design would not only make possible the adaptation of the old pass to meet the new conditions, but in addition its effective-
Abstract No. 46

A suggestion for pool fishpasses:
Replacement of orifices by
Short Tubes Fitted with
Baffles

Diagram of Baffles

Spacing of obstacles in meters

Discharge in liters per second

End View

Side View

Head 0.35 m
Head 0.30 m
Head 0.25 m
Head 0.20 m
Head 0.15 m

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ness would be improved. If applied to new fishpasses, the design should result in a reduced cost of construction."

47. Schmassmann, W., "Die Wirksamkeit der verschiedenen Fischaufstiegsvorrichtungen an Stauwehren, ihre Notwendigkeit und Anwendbarkeit im Einzelfalle" (The effectiveness of various arrangements for the ascent of fish at dams; the need for such arrangements and their practicability in individual cases), Reprint from Schweizerische Fischereizeitung Nos. 9 and 10, 1930. (Paper given at the "Schweizerischen Fischereitage", Olten, 1930.)

The author restricts the discussion to devices for upstream migrants. He emphasizes, however, that these devices must be suitable for the summer spawners (Barbus vulgaris, Chondrostoma nasus, etc.) as well as for salmon and trout. In fact, the author shows on the basis of hydrographical data on Swiss rivers and of facts concerning the migratory habits of different fishes, that for the Rhine and many other rivers coming from the Alps, the construction of fishpasses is justified primarily by the needs of the summer spawners. After this introduction (probably the most important part of the paper) the author surveys the fish counts at

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**SUMMER SPAWNS**

- Observations at the fishpasses
- Observations at the Augst locks
- Period of observations

**TROUT**

- Observations at the fishpasses
- Observations at the Augst locks
- Period of observations

**SALMON**

- According to the number caught
- Observations at the Augst locks

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**Distribution of Yearly Migration up the Rhine and Aare**

Abstract No. 47
fishpasses made by the "Schweizerisch-Badische Sachverständigen Kommission für die Fischerei im Oberrhein" (Swiss-Badensic Expert Committee for the Fisheries of the Upper Rhine) and compares them with the velocity measurements on the same passes made by the Swiss engineer Bitterli. He tries to find in these results a justification for his opinion that a velocity of 1.8 meters should not be exceeded substantially in the submerged orifices nor at any other place. If this condition is fulfilled, the author believes the fish will practically always use the submerged orifice and will readily negotiate the pass. If, on the other hand, the velocity in the submerged orifice is much higher, while in the overfall openings of the obstacles the velocity is small, the fish will more often prefer the latter, but some fish will not negotiate the pass at all. He therefore strongly recommends that all fishpasses be built with submerged orifices, arranging in addition, for other reasons, overfall openings at the tops of the obstacles, and that the height of the single step from pool to pool be made 17 to 18 centimeters only. He adds the following interesting remarks:

"If some of our fishpasses which serve acceptably for the summer spawners are only in exceptional cases negotiated by salmon, we must attribute this failure not so much to the system chosen as to the insufficient depth of these passes. The salmon prefer to swim, as every salmon fisherman knows, at a depth under the water surface such that they cannot be seen easily. To make fishpasses two meters deep will not cause any technical difficulty."

The almost complete failure of the Denil-imitation fishpass at Augst Whylen is due to the high velocity of about 4 m. and to the insufficient size of the cross-section.

The author is very much opposed to the use of fish sluices. As to the efficiency of fish lifts he expects a decision from the large fish lifts at Kembs which were at the time of this lecture in the planning stage. He seems, however, to be somewhat skeptical as to the value of this device.

48a. Denil, G., "Les échelles à poissons et leur application aux barrages de Meuse et d'Ourthe" (Fishpasses and their application at the Meuse and Ourthe dams), Annales des Travaux Publics de Belgique, 150 pp. and 5 large plates, 1909.

1 In a personal discussion with the present writer, Dr. Schmassmann emphasized that this extremely conservative recommendation is adapted to the needs of the migrant salmon arriving in fatigued condition in Swiss waters. He admitted that under different conditions, for fishpasses in Norway for example, much less conservative rules may well serve the purpose.
Model Channel

Velocity as a Function of Angle of Slope

Vertical Velocity Distributions

DENIL'S SYSTEM IN ITS FIRST STAGE

Abstract No. 48a
In this paper the author made known his now famous fishpass design in its original form, explained the ideas which underlie his work and gave data concerning his measurements on models, and described in detail the first passes built according to such designs. Some of the results of the laboratory measurements are reproduced. As to the underlying general observations and ideas it will be sufficient to give some of the most characteristic sentences of the paper in translation:

"The jumping ability of the salmon is remarkable; it is able to jump as high as 2 m. above the water, and sometimes even more. The author has seen salmon by an instantaneous effort — a 'jump within the water,' so to speak — enter a jet the mean velocity of which was as high as 5 m. per sec. with a surface velocity of 5.85 m. per sec. The salmon after having entered this jet advanced in it for a few meters.

"On the other hand, 2.6 m. is a velocity which can be faced by most of the migrating fishes for a practically unlimited length of travel, but for at least 14 m., provided that they are urged to the effort by their migratory instinct."

As to the properties of a good fishpass, the author sets up these requirements:

a. Symmetry of the passage.
b. A "continuous" stream.
c. Accessibility of the passage to light.
d. A noisy fishpass (échelle sonore); it has a good chance to be noticed from a distance by the fish and thus attract them.
e. Locally restricted cross-sections should have a minimum breadth of 30 cm. and a minimum depth of 25 cm., while normal dimensions of 60 cm. x 50 cm. should be required.
f. Since the fish tend to swim near the surface of the stream, the fishpass should enable them to do so.

Many of the views expressed in this paper are made obsolete by later investigations of the same author (See Abs. No. 6) and of others. This early publication is nevertheless interesting as one of the milestones in the progress of fishpass research and design.

For a short account of Denil's system in the early stage of its development see the article which follows.


The article is mainly descriptive and is well illustrated. The author emphasizes the possibility and value of model experiments according to Froude's law of similarity.

The author gives a fairly detailed description with diagrams and some photographs of the Denil fishpasses on the Meuse. (Some of them are described in Denil’s own publications). The author assumes that Denil has purposely used the “convergent” type near the banks and the “divergent” in the piers (an assumption which is hardly justified). The paper ends with some critical remarks from which the following may be noted.

The system with the secondary streamlines converging towards the axis appears to be preferable since this disposition results in the longitudinal velocity of the main stream being well dissipated in the middle third of the breadth, forming an easy passage for the salmon. As to the location of the fishpass as a whole, the author assumes that near the shore seems to be preferable because there the tailwater is usually comparatively quiet, and since fish probably always seek the way of lesser resistance, they will find the fishpass entrance more readily. The author however, is not very positive about this point and considers the fish-count data available as insufficient for a decision.

Lachadenède’s schematic explanation of the functioning of two types of Denil fishways

Abstract No. 49

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The Denil passes are in the opinion of the author too expensive. Each fishpass of this type, for an obstacle of about 4 or 5 meters in height, costs at least 200,000 francs (probably French francs are meant).

The author recognizes these more recent Denil passes to be very much superior with regard to energy dissipation compared with the early Denil passes of 1909, but he is reserved in his opinion as to whether a very high rate of energy dissipation is desirable. He considers a more thorough investigation of the use of the passes by the fish to be of great importance, especially of those nearest the mouth of a river.


The author starts with the description of an ancient cathedral at Oloron on which the salmon fisheries are represented as one of the "four main industries" of the earth, and he concludes that at the time when these sculptures were made salmon fisheries must have been an extremely important and prosperous industry in this part of France. He adds that as early as 1662 in the province of Bearn, a regulation was issued imposing on the proprietor of any dam or weir the duty to construct a passage for fish suitable both for ascent and descent. The author considers this regulation of 1662 in several details much more rational and scientific than the French law of 1829. He shows that the regulation of 1662 was put into practice through the construction of a number of fishpasses which were always placed in the stream, not along the shores, so that the fish could easily find them. They were not pool-and-jet fishpasses, but simple, steep, broad open channels, the bottoms of which were roughened by bundles of branches. The great breadth (about 4 m.) was probably chosen because the fishpasses served as timber-floating channels as well. Since the French government in 1927 made very strict regulations for the protection of salmon in the very few French rivers where it survives, the construction of a considerable number of fishpasses has become the order of the day. In some cases the old, broad fishpasses were utilized by repairing them, reducing their breadth to 1.5 or 2 meters, and replacing the moderately effective (and also entirely neglected) old bottom-roughnesses by new ones of scientific design. The author's
design for these energy-dissipating obstacles is described and discussed in his paper of 1935 (See Abs. No. 51). In the present paper he gives mainly laboratory results obtained at the hydraulic laboratory of Banleve. Some results of the author’s experiments are as follows:

For a slope of 25 per cent and a depth varying between 36 and 93 cm. above the obstacles, the velocity (average?) for the prototype varied between 3 and 4.5 m. per sec. This is considered by the author as too high a velocity.

For a slope of 15 per cent and a depth varying between 48 and 77 cm. above the obstacles, the velocity (average?) varied between 3 and 3.7 per sec. This is considered as acceptable. For a 10 per cent slope a slight further reduction of velocity is attained. The author stresses that the water is perfectly free from excessive aeration or “white water.”

The author emphasizes the simplicity and “rustic” nature of the obstacles. He states that they can be easily built in timber or in 3-mm. sheet steel and attached on the bottom of a concrete or masonry channel.

51. de Lachadenede, “Échelles à saumons et résultats obtenues sur les Gaves” (Salmon passes and results obtained on the Gave rivers), Bulletin Française de Pisciculture 8, pp. 4-10.

The author describes in a few words some examples of the Denil system and adds the following critical remarks. These fishpasses did not give complete satisfaction. Though they are probably ideal from the hydraulic point of view, they do not seem to be free from defects from the fisheries’ point of view. The re-entering secondary stream falls on the fish’s back giving it the impression of being submerged. It tries to escape this unusual influence by attempting to jump. The breadth of 50 cm. is in the author’s opinion hardly sufficient for salmon. Finally, the energy dissipation is so complete that the stream issuing from the fishway is insufficient to attract the fish.

Utilizing all of these observations, the author constructed a modified Denil fishpass. The re-issuing secondary streams are completely distributed over the rather considerable breadth of 150 cm. The author describes five examples of these fishpasses constructed with slopes of 10 to 15 per cent. For a 15 per cent slope the author found a velocity of 3.0 m. (probably mean velocity).
A Simple Wide Fishpass Based Upon Denil's Ideas

Abstract No 51

52a. Landmark, "Om Fiskvägar eller Laxtrappor" (Fishpasses or salmon ladders), Svensk Fiskeritidskrift, 1904.

This is a concise description of the particular form of pool-and-jet fishpass which has been suggested by the author and built with considerable success in Sweden and Norway.

52b. Carl Schmidt, "Fiskvägar" (Fishways), Upfinningarnas bok., Vol. VI, pp. 432-439.

This is a well illustrated authoritative outline of the fishway problem by the Fishery-engineer of the Swedish State. Salmon passes and young eel ladders are treated in some detail. Amongst the various types of the former the Landmark-Design is recommended and illustrated by good examples. The author explains the arrangements by which a fishway built mainly for salmon is adapted also for the upstream migration of the young eel. In addition he shows the "Swedish Standard Design" fishways for young eel only.
For earlier American publications by Landmark see Refs. No. 52c, 52d.


52d. Landmark, A., "Fishways on River Sire," Ibid., pp. 52-55, 1884.


This is a well-illustrated description of the fishpass types most familiar in England and Scotland. Recent progress in design is not taken into account. Biological, economic, and legal implications of the fishpass problem are discussed at some length.


In Section I, after prefatory notes and a short description of the experimental facilities, some preliminary experiments of the authors concerning jet dispersion in chambers are described and their significance for pool-and-jet fishpasses explained. Also, the authors' experiments concerning the resistance to be overcome by a fish swimming upstream are reported, and it is shown that the new data secured are on the whole decidedly favorable to Denil's view concerning this controversial question of fundamental importance. (See pages 8 and 9 of this bibliography.)

In Section II the authors show that a wide variety of energy dissipators fitted into steep channels are in their hydraulic action identical or closely allied to G. Denil's early design. They show, in

![Diagram of fishpass design](http://ir.uiowa.edu/uisie/23)
addition, that Denil’s more recent improved principle of energy dissipation is also representative of a wide variety of possible solutions and that it can be incorporated — with moderate loss in energy dissipating efficiency — in a substantially simplified form. The new design is suggested particularly for fishpasses of large cross-section with moderate headwater fluctuation.

In Section III, a new design based upon abrupt deflection of a submerged jet immediately at its issue is proposed and its hydraulic properties analyzed. It is shown on the basis of model experiments that this system can be used with advantage for slopes up to 1.5 for fishpasses of medium-sized cross-section.

Section IV recapitulates the practical conclusions reached in the course of the work and gives some additional recommendations to the designer.

In the appendices, study tours in Scandinavia and Scotland are reported, and the authors’ laboratory experiments for the clarification of certain controversial hydraulic properties of the familiar pool-overfall-jet fishpass are described.


This is a concise restatement of the results of Sections II and III of the preceding paper (54a) with emphasis upon the general
mechanics of the fluid motion phenomena involved, rather than on specific applications to fishpasses.

Titles of some older fishway papers (1864-1914) published in the English language:

60. Papers relating to the improvement of the salmon fisheries in the district of the river Girvan in the county of Ayr, with reported six plans by J. Leslie as to the means of facilitating the ascent of salmon over the mills, Edinburgh, 1872.
61. Warrall, James, Report of the Commissioner for the Restoration of the Inland Fisheries . . . including his special report to the senate on the subject of fish ladders, Reports State Com. Fish. II, 1865-72.


Titles of some more recent fishway publications (from 1921-1937) in the English language:


89. Michaelis, "Vortrag über Fischpässe" (A lecture on fishpasses), Zirk. d. deutschen Fisch.-Ver., p. 76, 1880.

90. Michaelis, K., "Fischzucht. Fischpässe" (Fish breeding. Fishpasses), Amtliche Berichte 1, Berlin, 1880 (1881).

91. Keller, H., "Die Anlage der Fischwege" (The design of fishways), Sonderabdruck aus dem Zentralblatt der Bauverwaltung, Berlin, 1885.


93. Fastenau, "Einige Mitteilungen über Lachslleitern" (Some facts concerning salmon ladders), Zirk. d. deutschen Fisch.-Ver., p. 39, 1873.

94. Hetting, M. G., "Veiledning til at bygge laxe-trapper" (Instructions as to how a salmon ladder should be constructed), No. 22, Christiania, 1867.


97. Meyer, "Die Fischpässe und die Lachsfischerei in der Ems und ihren Nebenflüssen" (Fishpasses and salmon fishery in the river Ems and its tributaries), Zirk. d. deutschen Fisch.-Ver., p. 5, 1889.


101. "Die Lachsleiter in Leibitsch" (The salmon pass at Leibitsch), Zirk. d. deutschen Fisch.-Ver., p. 11, 1885.


110. Article on Two-compartment Fishladder (Bauart Abraham), Zentralblatt der Bauverwaltung, No. 103, 1920.

Titles of some more recent literature (since 1920) in languages other than English:

111. Frischholz, Dr., “Anlage und Betrieb von Fischpässen” (The construction and management of fishpasses), 137 pp., illus., plates, diagrams. Handbuch der Binnenfischerei Mitteleuropas, Vol. 6, No. 1, 1924.

112. Schmassmann, “Über den Aufstieg der Fische durch die Fischpässe an den Stauwehren” (The ascent of fish through fishpasses at weirs), Schweizerische Fischereizeitung, 1924.


114. Koch, “Der rechtsrheinische Fischnap am Kraftwerke Laufenburg” (The fishpass on the right bank of the Rhine at Laufenburg), Badische Fischereizeitung, 1933.

Many papers discussed or mentioned in other sections of this bibliography contain some data or touch upon fishways proper. See particularly abstracts No. 6, 6a, 125a, 128, 130.
B. Fish Elevators and Fish Sluices


"The Wheeler device consists of a hollow, vertical tube, cylindrical or rectangular in shape and equipped with one gate near the bottom and another near the top. This hollow tube is installed as a part of the dam in such manner that the lower gate is at about the same elevation as the water below the dam and the upper gate about level with the water above the dam. The operation begins with the lower gate open and the upper closed.

"Water admitted from above the dam flows out through the lower gate, attracting the fish into the interior of the tube. After a predetermined time interval the lower gate closes and the tube fills with water admitted from the bottom. When the tube is about two-thirds full the upper gate opens and the filling operation is completed through the upper gate. The interior of the tube is equipped with a close fitting screen supported by floats two or three feet below the surface of the water. This screen rises with the rise of water in the tube and keeps the fish swimming near the top of the water column. After entering the device through the lower gate the fish are confined by a trap. When the tube has filled, a suitable opening in the screen allows the fish to pass through the upper gate to the waters above the dam. After a predetermined time interval the upper gate closes and the device empties through a valve at the bottom. The process is then repeated. Operation of the lift is entirely automatic; movement of the gates is controlled by a small motor driving suitable cams."

The rest of the article describes tests which were made of this device. The tests were considered highly satisfactory.


This article is a brief description of the tests of the Wheeler Patent Fish Lift which is explained fully in Abs. No. 115a.


This article states plans for the experiment with a fish elevator which are described in Ref. No. 116b.


The experiment mentioned in Ref. No. 116a is described and its results discussed.
117. Otterström, C. V., "Fiske Elevatorer," Reprint from Ferskvandfiskeri­
bladet, Vol. 34, No. 11, 7 pp., 1936.

The author first discusses the large fish elevator of the Rhine at
Kembs ‘‘System E. Gutzwiller’’ (See Abs. No. 43a) and the three
fish elevators constructed in Finland according to Dr. P. Brofeldt’s
system patented in Finland. He describes in greater detail the one
at Aborrfors, Kymmene Älv (southern Finland). The author dis­
cusses the danger of disturbance of the machinery by trash, possi­
bility of ice difficulties, etc. He considers none of these difficulties to
be prohibitive, however. In the author’s opinion the crucial point
is the attraction of the fish. Whether a fishpass or fish elevator is
constructed, it is of equal importance to find a proper place for
the downstream entrance, but this problem may be easier to solve
in certain cases for an elevator, than for a fishpass. Considerable
advantages, however, exist in favor of the elevator only if the weir
is high, substantially above 10 m. A short bibliography is added
to the paper.

118. Gottberg, ‘‘Fiskhissen’’ (The fish elevator), Fiskeritidskrift for Fin­
land, 1933.

This is a description of the fish elevator at Aborrfors in southern
Finland, which was the first built in northern Europe. (See also
Abs. No. 117 and Ref. No. 119.)

119. Brofeldt, ‘‘Fiskhissen, en ny anordning för fiskens uppstigande’’ (The
fish elevator, a new device for the ascent of fish), Nysvensk Fiskeri­
tidskrift, 1933.

Titles of other papers concerning fish elevators and allied de­
vices:

120. Reeken, L., ‘‘Fischschleusen’’ (Fish sluices), Allg. Fischereizeitung, No.
12.

121. Bridston, M. E., ‘‘Fish Elevator Aids Spawning,’’ Scientific American,

122. ‘‘Elevators for Salmon,’’ Canadian fisherman, Vol. 12, No. 4, p. 97, 1925.

123. Kipp, D. H., ‘‘Elevators for Fish: At Last a Sure Method Had Been
Devised to get Fish over Dams,’’ Field and Stream, Vol. 36, No. 12,
Apr. 1932.

124. Harrison, C. W., ‘‘Suggested Method of Passing Fish over High Dams,’’

Many papers abstracted or mentioned in other sections of this
bibliography discuss fish elevators and fish sluices. See particularly
abstracts No. 39a, b, c, d, e, f; 43a; 44a, b; 47; 128.
III

PASSAGE OF FISH THROUGH TURBINES

MECHANICAL AND ELECTRICAL FISH SCREENS

125. Otterström, C. V., "Die Turbinen und die abwärts wandernden jungen Lachse und Forellen (Sowie Aale)" (The turbines and the young salmon and trout (as well as the eels) migrating downstream), Reprints from the Journal du Conseil International pour l'Exploration de la Mer; Part 1, 1931; Part 2, 1932; Part 3, 1936. (A Danish version of the study has been published in Sport-fiskeren, 1932-36.)

The author made a large number of experiments with different migratory fish, mainly young rainbow trout (Trutta Irridea), at a number of power stations. The experiments confirmed the opinion that young salmon and trout can pass with but little danger through large turbines having slow rotation and a small number of blades, while the danger is considerable in a fast rotating turbine with a large number of blades.1

The author found the eels to be endangered even by turbines of favorable properties, and he advocates the arrangement of special passages for the downstream-bound eel.

At the end of his paper the author gives a short abstract of three allied papers by other authors (See Abs. No. 125a, Refs. No. 125b, c.) He shows that these three investigations made with different methods and in different countries indicate the capacity of the smolt to endure fairly rapid considerable fluctuations in pressure. The author therefore concludes that the smolt very likely will complete without injury the passage through the turbines — which of course is always accompanied by rapid pressure variation — unless it suffers direct wounds by cutting or other local injuries mainly from the turbine blades.

1 The present writer considers the author's statement needs qualification in so far as fast-running turbines are concerned. During his study tour in Sweden the writer was informed by the engineers of the Swedish State Power Plant at Lilla Edet that official experiments with the cooperation of the State fishery authorities have established that the smolt can pass with almost complete safety through the turbines, which are very large but very fast-running Kaplan and Lavaczek turbines. On this basis the fishery authorities consented to the removal of the fish screens.
This is an official statement of the French fishery authorities, representing the collective effort of several experts. L. Kreitman contributes a report of his unusual experimental results and theorizes concerning the passage of fish through turbines. (He even suggests a formula for the computation of the survival-chances of fish making such a passage.)

This paper is a review of the publications of Holzer in "Wasserkraft und Wasserwirtschaft," 1931, and in "Allgemeine Fischereizeitung," 1932, consisting of reports of his research at the Berlin Institute of Technology made on behalf of "Deutscher Wasserkraft- und Wasserkraftverband" concerning electrical influences on fish and the application of this ichthyobiological research to electrical fish screens and also to electrical methods of fishing; the former studied and introduced in America before Holzer's more thorough investigations, the latter proposed by the Swedish engineer Moller. The reviewers consider the research of Holzer and his co-workers to be of great value not only to biologists, but to engineers of power stations and to the fisheries. The report deals mainly with the biological facts and their application to fish screens of power stations. According to American experience, the electrical fish screens stop 92 to 99 per cent of all fish. In the German research conducted under less favorable circumstances, the effectiveness was found to be 92 per cent.

The authors conclude with an appeal for continued research in the electrical fish screen problem, and hope that France will par-
participate in this work, which is of considerable economic importance to the power stations.


This article points out the successful use of electrical fields in keeping fish from wasting their energy trying to go up tailraces of power plants and from getting stranded in irrigation canals. It is stated that the installation expense is very small and the cost of operation negligible. The screens consist of electrodes at 6-ft. spacing, a sketch of which appears in the article.


The paper is based upon the authors' work with the U. S. Bureau of Fisheries. They acted as advisers or designers for a considerable number of fishways and inspected practically every existing type of fish screen and fishway in the Pacific Northwest and in Alaska. After having given some valuable observations and suggestions concerning fish ladders (good illustrations are given of some large pool and overfall fishpasses), they discuss fish screens and define their various purposes as follows:

"Fish screens may well be treated under two headings, mechanical and electric. Mechanical screens are used to prevent migrating fish from passing into irrigation and power diversions or similar dangerous waterways. Electric screens have been used by the U. S. Bureau of Fisheries to screen the intakes of irrigation and power diversions, to guard tailrace flows against the entrance of upstream—migrating salmon and steelhead and to guide upstream-migrating salmon to counting weirs."

The authors consider the most efficient as well as economical mechanical screen to be the type of revolving fish screen which was developed by the Oregon Game Commission in 1921 and later adopted by the Division of Fisheries of the State of Washington, as well as by the U. S. Bureau of Fisheries. As to electrical fish screens, the authors recommend the "'insulated type of screen employing a double row of large diameter pipe electrodes energized with ordinary 60-cycle alternating current'" which was developed by the research of F. O. McMillan, Research Professor at Oregon State College, and later tested for the U. S. Bureau of Fisheries by the authors. The spacing recommended is 4 ft. from center to center in each row and 6 ft. from center to center be-
tween the rows. They call attention to the necessity of providing a properly located bypass channel for the downstream migrants. Similarly, if an electrical screen is built to prevent upstream migrants from entering tailraces, there should be enough water in the river channel above the tailrace discharge to attract the fish into it and thence to the fishway at the dam.

Examples are given of successful revolving screens and electrical screens with diagrams and photographs.

The authors call attention, however, to practical difficulties for prospective users of electrical screens. They mention the possible liability in regard to patent rights. Further, they emphasize the serious difficulties caused by possible antagonism of the public when some fish are killed or damaged by fish screens, even though the damage may be negligible compared with the resulting benefits.\(^1\)


The great danger caused by irrigation systems to the salmon and steelhead trout fisheries is shown. On the basis of the reports of O. W. Lindgren and John Spencer the rotary and parallel bar fish screens devised by the Bureau of Fisheries to counteract this danger in the Pacific Northwest are described and some of the results obtained are analyzed.

130. United States Department of the Interior, Bureau of Reclamation, "Migratory Fish Control at Roza Diversion Dam, Yakima Project, Washington," (mimeographed), 1940.

The paper gives a description (with plan and elevation) of the elaborate system of fish protecting measures arranged at this dam. The devices for the security of the young downstream migrants, (fish screens, bypasses, and sand sluices) are particularly interesting.

131. Gallois and Drouin de Bouville, "Grilles tournantes et grilles électriques aux États Unis en 1931" (Rotating and electric screens in the United States in 1931), Bulletin Française de Pisciculture 6, pp. 63-69, 1933.

Continuing their previous report and on the basis of some newer publications of the Bureau of Fisheries (Elmer Higgins), the

\(^1\) "Complete abandonment" of the use of the device by the U. S. Bureau of Fisheries as reported in a French publication (See Abs. No. 131) is, however, not mentioned in the present publication. It appears that the French authors misunderstood certain decisions of the Bureau of Fisheries.
authors review American progress in fish screen design and construction. They add the following recapitulation and critical remarks:

"The rotating screen is a simple, sturdy, and comparatively inexpensive device. It does its work excellently and needs but very little attention and maintenance. It may be used wherever electricity is available for the motor of the screen.

"The electrical screen, on the other hand, despite considerable progress since its invention and the rational rules for its design given by Dr. Holzer in 1931, remains a rather delicate device, and one requiring steady attention and vigilance. The Bureau of Fisheries has decided not to use it in the future. This is due to protests of fishermen, partly quite unjustified, against the fish screen plant at Gold Bay. The complete abandonment of electrical fish screens has been made in the United States only very reluctantly because it is the only type which is free from hydraulic head losses.

"If, in any country, this ingenious electrical device is again applied, particular care will have to be taken to isolate the electric lines. Even in this case, however, high voltage lines in the immediate vicinity are not without danger along a river. A possible failure of cables may make the river the conductor of the high tension line, endangering the fishermen as well as the fish."

132. Gallois, C. and Drouin de Bouville, "Nouveaux dispositives pour interdire aux poissons l'aces des derivations hydrauliques" (New devices to prevent fish from entering hydraulic plants), Bulletin Francaise de Pisciculture 4, pp. 73-80, 135-139, 169-178, 1931.


See also abstracts No. 134, 139.

2 See Abs. No. 128.
IV. SUBSTITUTES FOR FISHWAYS

134. Alm, Gunnar, "Fiskeri intresse och vattenkraften" (The interests of fisheries as affected by water power projects), with discussions by Velander, Hedin, and the author, Svenska Vattenkraftföreningens publica-
tioner No. 195, pp. 63-93. (Presented at the Eighteenth Annual Con-
vention of Svenska Vattenkraftföreningen, May 1927.)

The author gives a many-sided survey of the problems of protection of river fisheries against unfavorable conditions caused by water power developments, with particular reference to the salmon and eel which are the most important part of the Swedish river fisheries. After an introduction covering the biological aspects, the author discusses the particular nature of the disturbance caused to the different fish species by power stations and stresses the point, not so generally recognized, that under certain climatic conditions, as prevail in Sweden, not only the power stations themselves, but also lake regulations arranged in connection with the energy utilization of the rivers may be a source of danger for certain fishes spawning late in the year, among them probably also for the salmon. The eggs of fishes laid in the fall, during a fairly high gage height in the lakes, may, in consequence of the emptying in the winter, come to lay dry or to freeze in and be smashed by the ice, thus being destroyed. Different years may have widely variable hydrographic conditions so that the possibility of losses for the fisheries should be investigated for all conditions which might occur.

Coming back to the more obvious dangers caused by power stations, the author discusses the system of fishways and fish screens which may be necessary to eliminate the dangers. He discusses also the proper placement and design of fish screens. He shows, however, that in certain cases the construction of fishways and screens would not be justified. For example, if upstream from power station A which is under construction, another power station B is planned for the near future, which will be built where the salmon has its spawning ground, it would be wholly unecono-

mical to furnish plant A with fishpasses which would probably lose all their value as soon as the construction of plant B was started. For such cases, and also for cases where fishways are constructed but cannot be expected to be 100 per cent effective, the author
stresses the importance of fish breeding measures. He uses "fish breeding" in the sense of fertilization of the eggs, hatching of the young fish, and planting of the young fish either immediately when hatched or after a period of growth in ponds. The author shows the great advantages of the latter method which is receiving increasing recognition. He discusses the development of fish breeding in different countries and shows that relative to the population, fish breeding is furthest advanced in Canada and Switzerland, somewhat less in the United States, and still less in the Scandinavian countries. He gives much data on examples of salmon and eel hatching plants in Sweden. In conclusion he gives data concerning the judicial status of fish protective measures for the different rivers in Sweden and his ideas of how the conflicting interests connected with the rivers should be balanced.

The discussion following the lecture contains some interesting points. The period during which fishpasses should be open, and the difference between the "spawning grounds" and the "feeding grounds for the newly hatched fish" are discussed. Both the paper and the discussions contain numerous diagrams and photographs.

See also the following reference:

135. Nordquist, "Søtvatten Fiske og Fiskodling" (Fresh water fisheries and fish breeding), Stockholm, 1922.

For the early development of this problem see the following reference:


See also several of the papers discussed or mentioned in the bibliography, particularly in Section V, especially No. 136.

137. Tornquist, Nils, "Laxtransporter vid Klarälven" (Salmon transportation along the Klar river), Svensk Fiskeritidskrift, 6 pp., 1935.

The original paper was not accessible to the writer. C. V. Otterström in his paper (Abst. No. 45) gives a short digest of Tornquist's article and adds some remarks of his own. The following passage is a free translation from Otterström.

One can simply catch the fish at the tailwater of the weirs and transport them in large tanks to the headwater; if there are several consecutive obstacles it may be advisable to transport the fish by car or railroad a fairly long distance, perhaps several kilometers upstream. When the migration of the salmon of Lake Vänern
(Sweden) was stopped by the construction of the Dejefors plant, about 100 years ago, the considerable fishing industry in the Norwegian part of Trysil-elv was disrupted. Recently, however, the salmon have been caught at the tailwater of Dejefors, transported 60 km upstream and released there. In the river Trysil, about 180 km farther upstream, the salmon fishery is again thriving. But this method is probably economical only for salmon and trout and hardly so for the smaller and less valuable fish.


It is shown that for the Grand Coulee Dam with its height of 370 ft. a system of ordinary fish ways could not constitute either an economically acceptable or a reliable solution.

Therefore a well conceived system of fish trapping, transporting, holding, ("ripening"), artificial hatching and rearing establishments as well as arrangements for the liberation of the young fish in tributaries was substituted.

The opinion shared by many biologists that "the salmon under favorable conditions will return to the stream where they were liberated rather than to the stream from which the eggs were taken," is the basis for the arrangements chosen.

The system of measures contains many important new ideas and features. One of the interesting features is that in the holding pond, where the fish are held until they are ready for spawning, strong artificial current is created because

"It is necessary for the chinook and steelhead to have a certain strength of current to fight against to use up the stored energy accumulated for the upstream migration and to complete the physiological processes of ripening. This process is not complete when the adult fish reaches the Rock Island Dam, and a period of several months must pass before it is ready to spawn."
V. MISCELLANEOUS PROBLEMS OF FISH PROTECTION, AND OF WATER UTILIZATION AND LIMNOLOGY IN GENERAL

139. The Commissioner of Fisheries, "Bonneville Dam and Protection of the Columbia River Fisheries," a report submitted to the President of the United States Senate, July 1937.

This is an authoritative statement attempting an appraisal of the problem in all its various aspects. After a short introduction giving indications of the importance of the problem, the natural history of the Columbia River fishes is summarized; then the history and economic importance of the fisheries is outlined in greater detail. The further chapters discuss the methods of fish protection at power dams, at irrigation and flood control projects, and protection against pollution. An important chapter deals with problems of fish propagation. The basic and general recommendations of the Commissioner concern questions of scientific investigation, national planning, and governmental control. Specific recommendations are added: first, concerning employment of a specialist for operation, checking and — if necessary — modification of the Bonneville Dam fish protective works; second, the screening of federal irrigation plants; and third, the extension of the fish cultural stations for the artificial propagation of salmon and other food fishes of the Columbia River basin.

For a shorter discussion of the same problem with particular reference to the design of the Bonneville fishways see the paper which follows.


See also Abs. No. 44a.


The author considers as a proper definition of limnology "pure and applied science concerning fresh water." He limits his study, however, to lakes and ponds and gives a broad outline for their study, both hydrological and hydro-biological.

141. Schmassmann, W., "Zur Tagung des Schweizerischen Wasserwirtschaftsverbandes in Olten" (Remarks regarding the meeting of the Swiss Asso-
The author considers the main merit of this meeting to have been the discussion between representatives of the fisheries and representatives of the water power interests. The author’s remarks are made under four headings:

1. **Necessity for a device for the upstream fish migration at dams.**

The conclusion of the author is:

"On the basis of research made in the last few years concerning fish migration, all fishery experts are today thoroughly convinced that with the exception of rivers having only trout, every dam requires the construction of a fishpass."

2. **The effectiveness of fishpasses.**

The author repeats his views developed through his work with the Swiss-Badensic Expert Committee concerning the requirements for construction of reliable fishpasses, and states that the main speaker of the meeting, Professor Fehlman, previously a decided opponent of fishpasses, has now accepted these results of the committee work.

3. **Fish elevator (fish lift).**

The author discusses the pros and cons of the fish lift and particularly of the system Gutzwiller. He also mentions the problem of attracting the fish. He considers the question of the quantity of water necessary for this purpose to be as yet unsolved.

4. **The Committee for the Investigation of Fish Passage Problems.**

Though the Swiss-Badensic Expert Committee obtained a great many results, and some of them led to successful reconstruction of some fishpasses abroad, the author is aware that it did not solve the entire problem of fish passage. He appreciates therefore the decision of the "Schweizerische Wasserwirtschaftsverband" to appoint a new committee for further work in this field.

The main purpose of the paper is "to explain to owners and tenants of fishery-rights that their struggle to guard fresh waters against pollution, though generally considered to be egotistical, is in actual fact valuable to the community." The author shows

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1 This exception is based upon the specific hydrologic-biologic conditions prevailing in Switzerland.
that the interests of fisheries and those of public hygiene are closely connected and almost always parallel. While they may come into conflict with the interests of industrial enterprise, they by no means necessarily do so.

The first chapter deals with variations of water-level. The author discusses the hydrographical properties of two different types of Swiss rivers, the first exemplified by the Birs at Münchenstein, the second by the Rhine at Basel. He shows that from the point of view of the fisheries the greatest danger is the pollution of the streams of the limestone mountains (Kalkgebirge), exemplified by the Birs, if the low stage comes in the summer. One day of extremely low water in the summer can destroy all of the fish in a polluted stream. These same hydrographical conditions are dangerous for a number of other uses served by the stream.

The second chapter deals with rolling, suspended, and dissolved materials and their sedimentation, and proposes to prove that "though the fish react much quicker and more intensely to a change in the properties of the river than does a power plant, it is in the interest of both to keep the water free from organic materials."

The third chapter deals with the "relation between surface water and ground water" and shows on the basis of the investigations of Hug and of Minder that the pollution of surface water under certain circumstances results in danger to the ground water and its use as a supply of drinking water.

The last chapter is entitled "Unsolved problems of water utilization" and begins with the statement that physical and biological processes in our fresh waters influence each other mutually. While in modern scientific limnology, botanists, zoologists, chemists, and geologists (we may add also hydraulic research engineers) cooperate in a unified study of fresh-water conditions, and the International Association for Pure and Applied Limnology serves appropriately the aims of this cooperation, a corresponding unified and impartial handling of the purely practical problems of water utilization is still lacking. The author mentions a number of unsolved practical problems in this field. He touches also upon some practical implications of recent bio-climatical research.

143. Sornay, "La truite arc-en-ciel et le repeuplement des rivières" (Rainbow trout and the restocking of the rivers), Bulletin Francaise de Pisciculture 6, pp. 185-192, 1934.

The paper is a contribution to the discussion of the possibility of
planting rainbow trout in rivers. It is based partly on original research by the author and partly on a critical consideration of the paper of Vouga (See also Abs. 141). The point of view of the author will be seen best through the following sentences concerning Vouga's work:

"...This effort, made methodically and with persistence, is interesting in the highest degree. But though it represents, no doubt, a positive instance of sedentary habits of the rainbow trout, it does not give by any means a final solution of the problem as a whole. The only thing one can conclude as a certainty is, in fact, that the young trout brought by Vouga into the upper Rhone belonged to a sedentary or semi-sedentary strain able to accomplish its whole life cycle in fresh water. The particular section of the Rhone in question being devoid of indigenous trout, the newly planted trout found abundant reserves of food... One must, however, see some further generations of these trout, the observations made so far not being quite sufficient."

This paper is a short abstract of the third and final report of Vouga, Chief Fishery Inspector of Neu Chatel Canton (Switzerland), concerning the stocking of the higher Rhone with rainbow trout in Haut Valais, of which he was one of the chief promoters. Some of the most important results of his work are as follows:

a. In Europe there are a number of varieties of rainbow trout and variations obtained by crossing.

b. These give strong and healthy young fish which can be utilized for new stocking.

c. The rainbow trout thrives in the cold water of the mountains. In other parts of European mountains rainbow trout could also be bred in the rivers coming from the glaciers. These new colonies, in turn, could be utilized for further improvement of the breed.

d. The descent of the rainbow trout to the sea is a mere legend.

The original paper by Vouga is published in "Bulletin Suisse de Peche et Pisciculture," Neuchatel, 1933.

The author shows by the example of the Lysbro and the trout pond which receives its water from this little stream that the drain-
age of a sour meadow into a stream can endanger its whole fish population as well as that of the fish ponds connected with it. Particularly if after a long period of drought, a sudden and intense rainfall occurs, and if the original water of the stream is very soft, the acidity of the drained meadow may kill all the fish.

An interesting bibliography is appended.

See on an allied subject the paper which follows.


Some older European literature (1804 to 1903) on various questions of fish breeding, fish protection, and fisheries.

147. Rienam, "Praktischer Abriss des Fischereywesens fur Oekonomen Cameralisten und Liebhaber der Fischereien" (An outline of practical fisheries for conservationists and friends of the fish), Leipzig, 1804.

148. Haak, H., "Die rationelle Fischzucht" (Rational fish breeding), Leipzig, 1872.


150. Dallmer, E., "Fische und Fischerei im süssen Wasser mit besonderer Berücksichtigung der Provinz Schleswig-Holstein" (The fish and fisheries in fresh water, with particular reference to the conditions in Schleswig-Holstein), Segeberg, 1877.


152. Von dem Borne, Max, "Das Wasser fur Fischerei und Fischzucht" (Fresh water for fish breeding and fisheries), Neudamm, 1887.


154. Von dem Borne, Max, "Die Fischerei-Verhältnisse des deutschen Reiches, Oesterreich-Ungarns, der Schweiz und Luxemburgs" (Conditions of the fisheries of Germany, Austria-Hungary, Switzerland, and Luxembourg), Berlin, 1880.


156. Lindemann, "Amtlicher Bericht uber die Internationale Fischereiausstellung in Berlin, 1880" (Official report concerning the fishery exhibition at Berlin, 1880).
157. Benecke, B., "Fische, Fischerei und Fischzucht in Ost- und Westpreussen" (Fish, fisheries, and fish breeding in East and West Prussia), Königsberg i. Pr., 1881.

158. Zenk, P., "Die Verunreinigung der Wasserläufe und die Fischerei" (Water pollution and fisheries), 1895.

159. Duge, F., Henking, H., Wilhelms, Ø., "Bericht über die Internationale Fischerei Ausstellung in St. Petersburg" (Report concerning the fishery exhibition at St. Petersburg), Berlin, 1902.

160. Eckstein, K., "Die Fischereiverhältnisse der Mark Brandenburg zu Anfang des 20 Jahrhunderts" (The situation of the fisheries in the province of Brandenburg at the beginning of the 20th century), Berlin, 1903.

Some literature (European and American) from 1913 to 1933.


163. Nordquist, O., "Vattendragens överbyggande och fiskeri interessets tillvaratagande" (Power plants and the protection of the interests of the fisheries), Svenska Vattenkraft föreningens publicationer, No. 90, 1917.

164. Agren, H., "Om sjöregleringar og fisket" (Concerning the regulations of lakes and the fish), Svensk fiskeritidskrift, 1919.

165. Dahl, Knud, "Undersöknings vid Tunhövd fjorden angående fiskens näringsförhållanden före och efter regleringen" (An investigation at Lake Tunhövd fjord concerning the food situation for fish before and after the regulation of the lake).

166. Fehlman, "Fischerei und Stauwehre" (Fisheries and Dams), Schweizerische Wasser- und Elektrizitätswirtschaft, 1930.

167. Redeke, H. C., "Les laboratoires flottantes de la Hollande" (Floating laboratories in the Netherlands), Bulletin Francaise de Pisciculture 6, pp. 89-93, 1933. (Fish biological laboratories).

See also Abs. No. 134 and Refs. No. 135, 136.
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