Canadian Journal of Fisheries and Aquatic Sciences
Journal canadien des sciences halieutiques et aquatiques

Fisheries and Oceans
Scientific Information and Publications Branch
Pêches et Océans
Direction de l'information et des publications scientifiques

210 Sparks St.
Ottawa K1A 0E6
Canada

Our file Notre dossier
J7303

March 22, 1983

Dr. Robert J. Behnke
Dept. of Fishery & Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523
U.S.A.

Dear Dr. Behnke:

Subject: J7303 -- Leary et al.

We solicit your advice on suitability of this manuscript for publication in the Canadian Journal of Fisheries and Aquatic Sciences as a Main Article.

A guide is given on the back of the enclosed form. Also, we commend the advice to referees in the CBE Style Manual (4th ed., p. 65-69).

Attention to the following will help expedite assessment:

> If you consider that a colleague should review it, either in your stead or jointly, please act accordingly.
>
> If it is impractical for you to send us a review within three weeks, please return the manuscript promptly and suggest another referee if possible.
>
> If the manuscript is difficult to evaluate because of inferior presentation, please indicate this on the comment form and give a brief supporting statement.
>
> If you wish to have the author(s) know you reviewed the manuscript, please say so in a covering letter or sign the comment form.

Yours sincerely,

[signature]

David G. Cook
Assistant Editor

2 copies review to

.../2

J7303

WESTSLOPE CUTTHROAT TROUT X RAINBOW TROUT HYBRIDS: HATCHING SUCCESS, GROWTH, AND SURVIVAL

Robb F. Leary,[1] Larry C. Peterson,[2] Daryl Jennings,[2]
Fred W. Allendorf,[1] and Kathy L. Knudsen[1].

[1]Department of Zoology
University of Montana
Missoula, Montana 59812

[2]U.S. Fish and Wildlife Service
Northwest Montana Fish and Wildlife Center
Kalispell, Montana 59901

Leary, Robb F., Larry C. Peterson, Daryl Jennings, Fred W. Allendorf, and Kathy L. Knudsen. Canadian Journal of Fisheries and Aquatic Sciences 00: 000-000.

Hybrids of female westslope cutthroat trout (*Salmo clarki lewisi*) x male rainbow trout (*Salmo gairdneri*) had slight but significantly greater 'eyed' and hatching success than pure westslope cutthroat trout. By 90 days after fertilization, however, the hybrids showed a significantly slower growth rate and lower survival than pure westslope cutthroat trout. The results indicate that there may be more genetic incompatibility between these species than is generally assumed, or that greatly different levels of genetic incompatibility exist between different populations of rainbow trout and westslope cutthroat trout.

Key words: rainbow trout, westslope cutthroat trout, hybrids, introgression

---

Send proofs to Robb F. Leary (406)243-5503.

INTRODUCTION

Most local populations of native *Salmo* present at the beginning of this century in the interior of western North America no longer exist (Behnke 1972). Mining, logging, grazing, irrigation, and road construction have reduced the amount of suitable habitat, and are believed to have favored the displacement of the native trout by introduced brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) (Behnke and Zarn 1976). The most important factor for the loss of the native trout populations, however, has been the introduction of rainbow trout (*Salmo gairdneri*) and subspecies of cutthroat trout (*Salmo clarki*) into waters outside their natural range. These introductions are believed to have resulted in widespread hybridization and introgression between the native and introduced trouts, resulting in the loss of the native trout gene pools (Behnke 1972).

The objective of this study was to compare westslope cutthroat trout (*Salmo clarki lewisi*) x rainbow trout hybrids with regard to hatching success, survival, and growth to westslope cutthroat trout under hatchery conditions. It has generally been assumed that there is little genetic incompatibility between the *Salmo* species of western North America. The fertility and viability of hybrid crosses compared to intraspecific crosses of these fishes, however, is not well known. It is important that the relative success of hybrid crosses compared to intraspecific crosses be examined. The results of such studies will provide a clearer understanding of the management problems and potentials of this phenomenon.

METHODS

A hatchery strain of westslope cutthroat trout and the Eagle Lake strain of rainbow trout were the sources of gametes in this study. Both of these strains are maintained as brood stocks at the Creston National Fish Hatchery, Creston, Montana. The Eagle Lake strain was acquired from the California Department of Fish and Game. These fish are native to Eagle Lake, California. The characteristics and history of this strain have been reviewed by McAfee (1966) and Busack and Gall (1980). The westslope cutthroat trout strain was acquired from the Montana Department of Fish, Wildlife, and Parks. This strain is derived from trout native to Hungry Horse Creek, Flathead County, Montana. The history of this strain has been reviewed by Allendorf and Phelps (1980).

The eggs from female westslope cutthroat trout were divided into two groups of approximately equal number. One lot of eggs from each female was fertilized with sperm from a male westslope cutthroat trout. The other lot was fertilized with sperm from a male rainbow trout. All of the eggs were incubated together so that any differences in 'eyed' success and hatching success between families could be attributed to genetics.

The eggs from each family were examined after they had reached the 'eyed' stage. The undeveloping eggs from each family were counted, removed, and preserved in a water:methyl alcohol:formalin:acetic acid solution (5:3:1:1). All of the eggs that did not reach the 'eyed' stage were examined for the presence of an embryo with a dissecting microscope.

All of the yolk sac fry were transferred into a single trough. Individuals were later identified as westslope cutthroat trout or as hybrids by electrophoretic analysis (Reinitz 1977; Phelps and Allendorf 1982).

The eggs from an additional one hundred female westslope cutthroat trout were fertilized with sperm from twenty male rainbow trout. Approximately 38,000 eggs were used. These crosses were made one week later than the half-sibling family crosses.

RESULTS

Eye and hatching success of half-sibling families

The percentage of eggs reaching the eyed stage varied among and between the hybrid and the intraspecific crosses (Table 1). Eleven of the 24 comparisons of eyed egg percentage between half-sibling families were significantly different (Table 1). In nine of these significant comparisons the hybrid cross had a higher percentage of eyed eggs. Furthermore, 18 of the hybrid families had a higher percentage of eyed eggs than their half-sibling westslope cutthroat trout (sign test $P = 0.023$). The overall percentage of eyed eggs was also slightly, but significantly, higher in the hybrid crosses than in the intraspecific crosses, 79.8% and 76.4%, respectively.

Almost all of the eyed eggs hatched in the hybrid and intraspecific crosses, 98.8% and 98.1%, respectively. Thus, the results from the comparison of relative hatching success between half-sibling families were nearly identical to those of eyed success.

Examination of the eggs that had not reached the eyed stage revealed that most of them in the westslope cutthroat trout and hybrid crosses did not have a detectable embryo, 89.7% and 90.1%, respectively. Thus, if an embryo developed to the stage at which it could be seen with a dissecting microscope (about 3 days) it had a 96% chance of hatching, regardless of the species of the male parent. These results indicate that the overall superiority of the hybrid crosses relative to the westslope cutthroat trout crosses in eyed egg and hatching percentage was probably due to the ability of the rainbow trout sperm to initiate the development of a higher proportion of eggs.

Growth and survival of half-sibling families

The mean length of the hybrids was significantly lower than the mean length of the westslope cutthroat trout at 89 days, (27.2 and 29.0 mm, respectively; $t = 3.33$, $p < 0.001$) and 112 days (33.6 and 40.1 mm; $t = 4.31$, $P < 0.001$) after fertilization. This size difference had proportionately increased between 89 and 112 days indicating that the hybrids grew at a slower rate. Between 89 and 112 days after fertilization many of the hybrid fish died. In the 89 day sample, 38.9% of the fish were hybrids. Only 6% of the fish were hybrids in the 112 day sample. Thus, the hybrids had slower growth and lower survival (Fig. 1) than the westslope cutthroat trout. Shortly after the 112 day sample was taken this experiment was terminated due to the low survival of the hybrids.

Growth and survival of hybrids raised separately

Only thirty-five percent of the eggs reached the eyed stage in these hybrid crosses and most of these hatched. Shortly after these hybrids were 90 days old there was a few week period of heavy mortality. Only 12.3% of the hybrids that hatched were alive 150 days after fertilization. After this period of heavy mortality, survival stabilized, and the remaining hybrids are still being raised.

DISCUSSION

The slower growth and higher mortality of the hybrids are probably not independent phenomenon. They cannot be attributed to competition between the hybrids and the westslope cutthroat trout since high mortality was observed at the same age in the hybrids raised without westslope cutthroat trout, and these hybrids also had slow growth. Apparently the slow growth and low survival of the hybrids are the result of a genetic incompatibility between the Eagle Lake rainbow trout and the westslope cutthroat trout. The genetic incompatibility between these strains was not evident until 90 days after fertilization. We find this result surprising since we would have predicted that genetic incompatibilities would be evident in reduced eyed and hatching success in the hybrid crosses. We do not know why the genetic incompatibility was not evident until this relatively late stage and through what specific mechanism it operates.

Similar results, however, have been reported in other hybrid crosses. Gould (1966) observed greater than 90% hatching success in a golden trout (Salmo aquabonita) female x cutthroat trout male cross. High mortality ensued in the advanced fry stage and apparently only a small percentage of the individuals survived. Gold et al. (1976) observed 78% hatching success in a rainbow trout female x golden trout male cross. Shortly after the fry had absorbed the yolk sac, however, 84.2% of them died. The high mortality in this cross, however, may have been due to environmental reasons, but a genetic incompatibility cannot be dismissed. Gold et al. (1979) also were not able to produce any backcross individuals by crossing one of the surviving progeny to a rainbow trout male.

The obvious difference in eyed egg success between the half-sibling family hybrid crosses and the other hybrid crosses is best explained by the one week time difference between the crosses. The half-sibling crosses were made during the peak of the westslope cutthroat trout spawning period. In this strain, westslope crosses made before or after this time consistently have reduced eyed and hatching success (Peterson and Jennings, unpublished data).

Our data suggest that there may be more genetic incompatibility between the westslope cutthroat trout and the rainbow trout than is generally assumed. This is an important observation since hybridization and introgression between these fishes in nature may also result in reduced reproductive potential as well as the loss of the native trout gene pools.

Electrophoretic data from natural populations indicates that introgressed populations of westslope cutthroat trout and rainbow trout are common (Allendorf and Phelps 1981; Leary and Allendorf unpublished data). The results from our experimental crosses, therefore, pose a question which we will attempt to answer with future crosses. Is the observed introgression between these fishes in nature due to the survival of relatively few hybrid progeny, or was the observed incompatibility in our hybrid crosses due to the nature of the crosses (female westslope x male rainbow), or is it specific to the Eagle Lake strain?

Different levels of genetic incompatibility between populations of one species and another has potential management implications. The preservation of the genetic resources of the remaining native trout populations in western North America is a goal of many management programs. In order to achieve this goal it is desirable that hatchery fish not be introduced into drainages that are inhabited by native trout populations. This, however, may be necessary in order to fulfill other management obligations. In these situations, therefore, it would be desirable to introduce hatchery strains that are known to have a high level of genetic incompatibility with the native species. This would minimize, or possibly prevent, the introgression between the native and introduced species.

ACKNOWLEDGEMENTS

This work was partially supported by National Science Foundation grants DEB-8004681 and ISP-8011449 to Fred W. Allendorf. We thank the Montana Department of Fish, Wildlife, and Parks for financial support awarded to Robb F. Leary. We also extend thanks to H. McPherson for stimulating conversation.

LITERATURE CITED

Allendorf, F. W., and S. R. Phelps. 1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Transactions of the American Fisheries Society 109:537-543.

Allendorf, F. W., and S. R. Phelps. 1981. Isozymes and the preservation of genetic variation in salmonid fishes. Ecological Bulletins (Stockholm) 34:37-52.

Behnke, R. J. 1972. The systematics of salmonid fishes of recently glaciated lakes. Journal Fisheries Research Board of Canada 29:639-671.

Behnke, R. J., and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. U.S.D.A. For. Serv. Gen. Tch. Rep. Rm-28, 45 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colorado.

Busack, C. A., and G. A. E. Gall. 1980. Ancestry of artificially propagated rainbow trout strains. California Fish and Game 66:17-24.

Gold, J. R., R. E. Pipkin, and G. A. E. Gall. 1976. Artificial hybridization between rainbow trout (Salmo gairdneri) and golden trout (Salmo aquabonita). Copeia 1976:179-183.

Gold, J. R., R. E. Pipkin, and G. A. E. Gall. 1979. Notes on a hybridization experiment between rainbow and golden trout. California Fish and Game 65:179-183.

Gould, W. R. 1966. Cutthroat trout (Salmo clarkii Richardson) x golden trout (Salmo aguabonita Jordan) hybrids. Copeia 1966:599-600.

McAfee, W. R. 1966. Eagle Lake rainbow trout. p 221-225. _In_ A. Calhoun (ed.). Inland fisheries management. State of California, the Resources Agency, Department of Fish and Game.

Phelps, S. R., and F. W. Allendorf. 1982. Genetic comparison of upper Missouri cutthroat trout to other _Salmo clarki lewisi_ populations. Proceedings Montana Academy of Sciences 41:14-22.

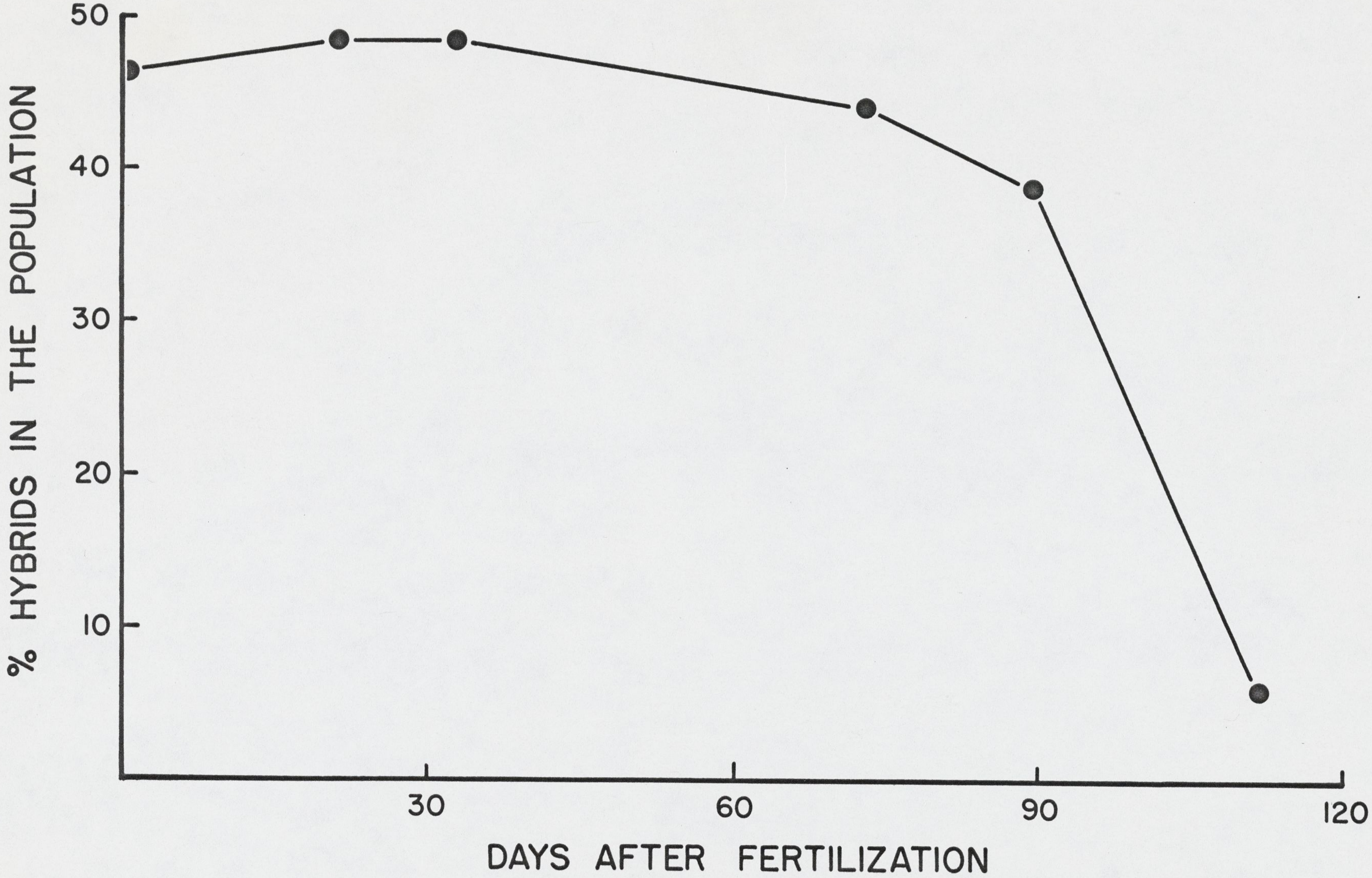
Reinitz, G. L. 1977. Electrophoretic distinction of rainbow trout (_Salmo gairdneri_), westslope cutthroat trout (_S. clarki_), and their hybrids. Journal Fisheries Research Board of Canada 34:1236-1239.

Table 1. Percentage of eggs attaining the eyed stage in families of westslope cutthroat trout and westslope cutthroat trout X rainbow trout hybrids.

	Westslope		Hybrid			
Female no.	Total eggs	% eyed	Total eggs	% eyed	Difference % eyed	Chi-square[1] (1 D.F.)
1	86	45.3	85	0.0	45.3	64.1***
2	160	94.4	149	40.9	53.5	102.3***
3	269	30.5	259	62.5	-32.0	54.6***
4	95	93.7	78	97.4	- 3.7	1.4
5	85	70.6	75	89.3	-18.7	8.6**
6	115	47.8	121	54.5	- 6.7	1.1
7	111	90.1	100	87.0	3.1	0.5
8	530	82.8	328	98.5	-15.7	49.9***
9	149	91.9	123	94.3	- 2.4	0.6
10	99	81.8	95	88.4	- 6.6	1.7
11	127	43.3	157	72.0	-28.7	23.9***
12	82	87.8	83	88.0	- 0.2	0.0
13	181	92.3	126	94.4	- 2.1	0.6
14	269	97.8	298	99.7	- 1.9	4.2*
15	166	86.7	127	97.6	-10.9	10.9**
16	143	93.0	117	86.3	6.7	3.2
17	179	91.1	127	90.6	0.5	0.1
18	95	74.7	187	84.5	- 9.8	3.9*
19	117	0.9	119	0.0	0.9	1.0
20	80	87.5	58	89.7	- 2.2	0.2
21	387	90.4	423	96.7	- 6.3	13.4***
22	439	96.8	390	96.9	- 0.1	0.0
23	280	91.4	225	94.2	- 2.8	1.4
24	212	0.0	168	3.0	- 3.0	6.4*
total	4456	76.4	4018	79.8	- 3.4	13.2***
total % hatched		75.0		78.8	- 3.8	16.2***

[1]* = P < 0.05, ** = P < 0.01, *** = P < 0.001.

Figure 1. Relative survival of westslope cutthroat trout X rainbow trout hybrids.


50
40
30
20
10
% HYBRIDS IN THE POPULATION
30
60
90
120
DAYS AFTER FERTILIZATION

Canadian Journal of Fisheries and Aquatic Sciences

Journal canadien des sciences halieutiques et aquatiques

Volume 40, No. 1, January 1983

Volume 40, n° 1, janvier 1983

Editorial

In an era of increasing specialization in science, the generalist journal has become less common. We believe that such journals serve the important function of communicating research results from many disciplines, thereby enabling readers to be kept abreast of the latest advances in a number of specialities. However, a major disadvantage of the generalist journal is the difficulty in defining an editorial policy that presents clearly to potential authors the types of papers that will be accepted or rejected.

There has been considerable confusion recently concerning our conditions for acceptance or rejection. In previous editorials we have stated that the *Journal* wants the best manuscripts authors have to offer in the broad field of fisheries and aquatic sciences. However, what has not generally been appreciated is that *Journal* policy has evolved as the state of the art of various disciplines has progressed. For example, as strong foundations in some were established, the cutting edge of research shifted to experimental science, modeling, and holistic environmental studies. Consequently, editors accepted baseline or descriptive papers only in emerging disciplines, leaving some authors with the impression that decisions were arbitrary. Obviously a clearer, more precise definition of the *Journal*'s editorial policy was needed.

Accordingly, the first and second meetings of the Editorial Board were largely devoted to discussion of these matters. The statement that follows distills those discussions into a policy statement on what a *Journal* article should contain. By necessity it is broad, but we hope it clearly embodies the essential qualities of a *Journal* paper.

The *Canadian Journal of Fisheries and Aquatic Sciences* encourages papers dealing in general with the aquatic sciences, and in particular with fisheries and aquatic organisms. Papers may concern cells, organisms, populations, ecosystems, or processes that affect aquatic production systems, and they should lead to identifiable conclusions or synthesis, which variously may amplify, modify, question or redirect accumulated knowledge embodied in contemporary perceptions of a particular state of aquatic sciences. They should demonstrate clearly their contribution to knowledge beyond

Éditorial

À une époque où la spécialisation scientifique s'accentue, les journaux à vocation générale se font plus rares. Nous croyons que de tels journaux jouent un rôle important, celui de communiquer les résultats de recherches effectuées dans un grand nombre de disciplines, permettant ainsi aux lecteurs de se tenir au courant des tout derniers progrès réalisés dans un certain nombre de spécialités. Cependant, pour ce genre de journal, le grand inconvénient est la difficulté d'établir une politique de rédaction qui indique clairement aux auteurs éventuels les genres de textes qui seront acceptés ou refusés.

Dernièrement, il y a eu beaucoup de confusion au sujet des conditions que nous avons fixées pour accepter ou refuser des textes. Dans des éditoriaux précédents, nous avons indiqué que le *Journal* recherche les meilleurs manuscrits que les auteurs peuvent offrir dans le vaste domaine des sciences halieutiques et aquatiques. Cependant, de façon générale, les gens n'ont pas saisi que la politique du *Journal* a évolué au rythme des progrès réalisés dans les diverses disciplines. Par exemple, alors que des bases solides étaient établies dans certaines disciplines, la recherche de pointe s'est tournée vers la science expérimentale, la modélisation et les études environnementales holistiques. Par conséquent, les rédacteurs ont accepté des articles de fond ou des articles descriptifs uniquement dans de nouvelles disciplines, donnant l'impression à certains auteurs que les décisions étaient arbitraires. De toute évidence, il fallait redéfinir de façon plus précise et plus claire la politique de rédaction du *Journal*.

En conséquence, les deux premières réunions du Comité de rédaction ont porté en grande partie sur ces questions. Est sorti de ces discussions l'énoncé de principe suivant sur ce que devrait contenir un article de *Journal*. Cet énoncé est forcément général, mais nous espérons qu'il résume clairement les qualités essentielles que doit avoir un article publié dans le *Journal*.

Le *Journal canadien des sciences halieutiques et aquatiques* publie des textes qui portent de façon générale sur les sciences aquatiques et en particulier sur les organismes halieutiques et aquatiques. Les textes peuvent avoir trait aux cellules, aux organismes, aux populations, aux écosystèmes the confirmatory state. Papers that apply standard techniques without breaking new methodological ground cannot be considered. Originality should relate to more than the particular (a certain year, place, taxon, or chemical compound) such that existing understanding is refined or reformulated.

It would assist the Editors if prospective authors identified briefly by covering letter, those aspects of their papers that in particular meet the foregoing objectives. Authors should recognize that clarity of intent and purpose of a paper, often well expressed in a covering letter to the Editor, also provides the same clarity to readers in general when suitably expressed in the introduction to a paper.

The *Journal* will continue to cover most disciplines in the aquatic sciences, thereby retaining its generalist orientation. We will encourage papers as just described and discourage those that have site-specific or local application, or confirm previously established principles. There must be an outer boundary to the *Journal*'s scope, however. Just because a paper concerns aquatic resources or reports research supported by the Federal Government does not automatically qualify it for consideration. For instance, theoretical physical oceanography, certain types of physical chemistry, waterfowl biology (unless it had a quantified impact on fish), and marine engineering are unsuitable disciplines for the *Journal*. Papers whose relevance to the *Journal*'s scope is debatable are sent to the Editorial Board for arbitration, with the benefit of doubt always given to the author.

We look forward to readers' responses to this Editorial, and as always, welcome any constructive comments.

J. WATSON
Editor-in-Chief

JOHANNA M. REINHART
Editor

ou aux processus qui influencent les systèmes de production aquatique et ils doivent aboutir à des conclusions ou synthèses précises qui, de diverses façons, peuvent accroître, modifier, remettre en question ou réorienter le bagage actuel des connaissances et perceptions dans une discipline donnée des sciences aquatiques. Ils doivent clairement démontrer qu'ils contribuent aux connaissances en faisant plus que corroborer des faits. Les textes qui appliquent des techniques standard sans apporter des innovations méthodologiques ne peuvent être retenus. L'originalité doit dépasser le caractère particulier (une année, un endroit, un taxon ou un composé chimique donné) et tenir à une épuration ou à une reformulation des connaissances actuelles.

Les auteurs éventuels aideraient les rédacteurs s'ils identifiaient brièvement, dans une lettre d'accompagnement, les aspects de leurs textes qui répondent particulièrement aux objectifs indiqués ci-dessus. Les auteurs sont en outre priés de noter que l'objectif d'un article, bien exprimé dans une lettre d'accompagnement adressée au rédacteur, éclairera également le lecteur s'il est bien expliqué dans l'introduction.

Le *Journal* continuera à couvrir la plupart des disciplines qui font partie des sciences aquatiques, conservant ainsi son orientation généraliste. Nous favoriserons les articles répondant aux critères précités et rejèterons ceux qui se rapportent à un endroit en particulier ou qui ont une portée locale, ou encore qui ne font que corroborer des principes déjà établis. La portée du *Journal* doit cependant être limitée. Ce n'est pas parce qu'un document traite de ressources aquatiques ou relate des recherches appuyées par le Gouvernement fédéral qu'il sera automatiquement pris en considération. Par exemple, l'aspect théorique de l'océanographie physique, certains genres de chimie physique, la biologie des oiseaux aquatiques (à moins que ceux-ci aient un effet quantifié sur les poissons) et le génie maritime sont des disciplines qui ne conviennent pas au *Journal*. Les documents dont le rapport avec les objectifs du *Journal* est discutable sont envoyés au Comité de rédaction pour arbitrage, le bénéfice du doute étant toujours laissé à l'auteur.

Nous espérons recevoir les réactions des lecteurs à cet éditorial et, comme toujours, nous accueillerons avec plaisir toute critique constructive.

J. WATSON
Rédacteur en chef

JOHANNA M. REINHART
Rédactrice

P.S. As you may know from our latest editorial (copy enclosed), we now exclude species-specific reports that offer no general advance in our understanding of the topic. Do you think that the general result concerning different levels of incompatability between Salmo populations and its management implications is sufficiently novel to warrant primary publication? Your comments on this and any other aspects of the work would be very much appreciated.

/jab