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An Updated Review of Grayling Biology, Impacts, and Management

Dr Tom G. Northcote
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PREFACE

This report originated from a presentation by Dr. Tom Northcote at the Arctic Grayling Workshop sponsored by the Peace/Williston Fish and Wildlife Compensation Program. The Workshop occurred on January 18 to 20, 2000, in Prince George, BC. The intent of this workshop was to gather data on Arctic grayling from British Columbia, Alberta, Northwest Territories, and Montana, USA. In addition, there was an exchange of ideas from many biologists discussing habitat preferences of Arctic grayling, harvest regulations, and basic biology (population dynamics, genetics, and community interactions). With all of this information, the future management of this species will be further defined and ultimately ensure the longevity of this species of special concern.

Dr. Tom Northcote was a keynote speaker at this workshop and has agreed to provide the Peace/Williston Fish and Wildlife Compensation Program with a condensed version of his presentation. The abstract for this presentation is also published in the Peace/Williston Fish and Wildlife Compensation Program report series No.210 titled "Arctic Grayling Workshop 2000". In addition, at the end of this report is a list or references compiled by Dr. Tom Northcote illustrating a literature review on Arctic grayling.

AN UPDATED REVIEW OF GRAYLING BIOLOGY, IMPACTS, AND MANAGEMENT

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INTRODUCTION

One might well question why yet another such review is needed. After all, I had reviewed this area with special reference to the Williston Reservoir watershed of British Columbia in the early 1990s (Northcote 1993), and followed it up shortly thereafter with a comparison of the biology and management of Arctic and European grayling (Northcote 1995).

The most compelling reason is that there has been an almost exponential increase in relevant grayling literature over the past few years. I found some 180 new references to my previous reviews, 122 of them since the mid 1990s, and I was by no means able to cover much of the "grey literature" in the time available, or to contact all of the active groups working in this field. In addition, more information is becoming available on Siberian / Asian populations of Arctic grayling, and on grayling in the Amur Basin as well as in Mongolia that is of great interest.

Armin Peter at the Swiss Federal Institute for Water Resources and Water Pollution Control, Kastanienbaum, kindly arranged a literature search for me on grayling references since 1994. Abigail Ingram, Institute of Freshwater Ecology, Wareham, England sent me her European grayling references, as did Henri Persat, University of Lyon, France and Michael Dedual, Switzerland (now New Zealand). Doug Fleming, Alaska State Fish and Wildlife, provided me with an update of much of the work going on there. Mrs. Lisa Northcote arranged for my use of NIWA library facilities in Wellington, New Zealand. Joe Nelson and Bill Tonn, University of Alberta, Edmonton also helped, as did many others. I would be most grateful to receive information on work missed or on new studies becoming available.

My interest in grayling began in 1952 when I had the opportunity, conducting limnological studies in northeastern B.C. for Peter Larkin, then Chief Fishery Biologist of the B.C. Game Commission, to see the Pine River grayling habitat and sample its fine grayling populations. Later in the 1970s I visited Arctic grayling habitat in the Angara River (outlet of Lake Baikal, Siberia) and saw the intensive "sport" fisheries there heavily dependent on grayling snagging. In 1993 I went back again to the upper Peace River tributaries, working on snorkeling census of grayling on the Burnt and Sukunka rivers, and in the mid 1990s enjoyed dry fly fishing for grayling there.

GRAYLING WORLD DISTRIBUTION

Arctic grayling, now extinct as natural populations in the Michigan area (Fig. 1), and in their most southern limits reduced at present to the Big Hole River system in the upper Missouri River, are broadly distributed across northern Canada from western drainages into Hudson Bay, through Alaska, across the Bering Strait into far Eastern Siberia and

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Kamchatka, through Siberia westward to the eastern slopes of the Ural Mountains where they contact the European grayling.

The latter as native populations extend throughout most of Europe to western France, much of Scandinavia and England and southern Scotland. Graylings of uncertain taxonomic status are found in the mid and upper Amur River basin (Fig. 1) and in parts of Mongolia.

THE GRAYLING LITERATURE

The decline in publication rate on Arctic grayling in the Michigan area since the mid 1880s has been counterbalanced by an increase in all other major parts of its range since then (Fig. 2), slowly in the Montana and Siberia / Asia areas, and much more rapidly in Canada / Alaska especially in the most recent decade.

The 186 grayling references that I reviewed can be partitioned into four broad subject areas, recognizing that some of these fit into two or more of the areas (Fig. 3). By far the most (158 out of the 186) deal with biological studies on grayling, about equally so for Arctic and European grayling, with a very few on Amur / Mongolian graylings. Some 42 consider environmental impacts on grayling (equally so for the Arctic and European species), 38 on fishery effects (heavily for Arctic, less so for European and Amur / Mongolian graylings), and 46 on management activities (nearly equally for Arctic and European graylings). Siberian / Asian Arctic grayling make small contributions to total percentages for all four subject areas (Fig. 3).

1. Grayling biology

The literature included in this review comes largely from that appearing after my 1993 and 1995 coverage although some references that I had missed then are added as well as a few others given previously of special interest. The references on Arctic, European and Amur / Mongolian grayling are first placed into four broad subject areas - biological studies, environmental impacts, fishery effects, and management activities as indicated respectively by the Roman numerals in squared brackets at the end of each one in the reference list. Two subject areas are further partitioned - biological studies into seven categories and management activities into four, as indicated by the Arabic numbers in normal parentheses behind the appropriate Roman numerals.

Recent references on grayling biology partitioned into the seven subject areas are shown in Figure 4. There are 44 on grayling species, stocks and genetics (most for Arctic grayling), 64 on estimates of population size and regulating factors (most again for Arctic grayling), 39 on habitat use and conditions (most for European grayling), 31 on spawning and development up to the emergence stage (about equal for Arctic and European grayling), 52 on various aspects of age, size and growth (far more for Arctic than for European or Amur / Mongolian grayling), 40 on movements, migrations and homing (most for Arctic grayling), and 20 on feeding (most for Arctic grayling).

Species, stocks and genetic references deal with morphological aspects (dorsal fin patterns, gill rakers), parasite faunas, growth rates, juvenile current responses, mitochondrial and nuclear DNA, and allozymes all of which show high regional differences. There will soon be a further upsurge of publications in this area with several groups input, some on Amur and Mongolian grayling.

The many studies on population size and its regulation include both field and laboratory work showing the role of competitive interaction and microhabitat segregation for several Arctic and European grayling populations. Also included are field studies on predation (pike, burbot, cormorants) in population regulation especially for European and Lake Baikal Arctic grayling.

A number of detailed field studies (some experimental) show the importance of shoreline, bank, and small tributary habitat for young grayling. Quantitative data are becoming available now on velocity, depth, substrate, and cover requirements for both Arctic and

European grayling. The marked shifts being demonstrated with day / night, season, and age / size all have high management significance.

Along with the many field studies on spawning, hatching and emergence of Arctic grayling, there is one of the first for northeastern Siberian and Okhotsk rivers. The first demonstration of night spawning using hydrophones and acoustic gear has been made for French stream populations. Other good field studies in this area for European grayling are coming from Belgian, Swiss and Norwegian populations.

Enclosure studies (Big Hole River, Montana) are showing that intraspecific competition has a greater negative effect on growth rate than does interspecific (brook trout) competition. Electrofishing is shown to decrease growth rates of Arctic grayling (experimental studies, Montana, Alaska stream populations). Several studies give broad coverage of size, age and growth for Siberian Arctic grayling, as well as for European grayling populations (UK, France, Norway), and a few for Amur / Mongolian grayling populations.

Field studies show patterns of juvenile migration from spawning to feeding habitats for Arctic grayling (including two Siberian populations), along with field and experimental work on French, Swiss, Norwegian, Swedish and western Russian populations of European grayling. Precise homing (radiotelemetry) has been demonstrated for Belgian populations with upstream spawning migrations of some 5 km and downstream return to the same pool / riffle sequence. In the upper Volga system, homing is shown to be 83 %.

The fewer feeding studies include experimental work on Alaska stream populations of Arctic grayling (modelling of drift feeding) and on Siberian reservoirs and rivers, for European grayling in Norwegian reservoirs and French rivers, and for Amur River basin grayling.

2. Environmental impacts

Studies on impoundments and diversions continue to dominate work in this area for both Arctic and European grayling. Bypass channels are showing promise of allowing effective grayling movement in Austrian rivers with suitable profile characteristics.

Pollution associated with organochlorine pesticides and heavy metals temporarily bound in sediments are sources of much contamination in both North American and Siberian Arctic grayling populations. In the later, levels are high enough to cause structural abnormalities. Sockeye salmon adults are shown to biotransport PCBs and DDT from marine sources to inland Alaskan Arctic grayling that have over two times higher the level than those populations with no salmon. Impaired feeding ability (up to 25 % lower) has been demonstrated in European grayling fry with relatively low induced levels (less than 3 µg / L) of methylmercury. Such levels can occur by diffuse atmospheric fallout. Increased aquatic iron and aluminum levels caused by forest harvesting can have harmful effects on Finnish European grayling.

3. Sport fishing effects

Catch and release fisheries are developing for the presently large eastern Siberian Arctic grayling. For many of these populations there are high incidences (up to 41 %) of jaw damage attesting to heavy overfishing and snagging effects.

In some heavily fished Swiss populations of European grayling there are very few older fish (94 % less than two years old, and 99.7 % less than three years old!). On a popular Norwegian river, angling hours per river kilometre may reach 2000 annually. In north England rivers overfishing and "culling" are listed as important causes of grayling decline. Overfishing occurs in tributaries of the Pechora River in the northwestern Urals.

For Amur grayling populations commercial fisheries in the late 1800s may have had serious effects as catches up to 27,000 kg are recorded from an upper basin tributary with

high catches of large grayling also being taken by anglers in the recent decades. Individuals up to nearly 2 kg can still be caught in that system.

4. Management activities

Some 42 recent references on grayling management can be partitioned into four main subject areas (Fig. 5), most on aquaculture / stocking, less on habitat restoration, and a few on angling regulations and on competitor or predator control.

Aquaculture, especially for European grayling in Sweden and elsewhere, is well developed with a recent doctoral thesis and many journal publications dealing with methods, feeds, and stocking results.

Catch and release angling is on the rise, particularly in the UK, but apparently not so in Siberia / Asia for Arctic grayling or for Amur / Mongolian grayling, except for that by European angling tour groups.

Stream habitat restoration specifically for Arctic grayling is showing great promise especially in Montana but also in B.C., Alberta, and Alaska, as well as for European grayling in parts of continental Europe (e.g. in Switzerland and Austria).

Migration bypass channels are being developed for European grayling blocked by weirs and dams in some parts of continental Europe where river profiles are suitable.

GRAYLING MANAGEMENT IN B.C. WILLISTON / DINOSAUR RESERVOIRS

Success will demand assertive approaches on four main fronts.

1. Fill serious gaps in basic grayling biology

Stock / metapopulation / genetic diversity work needs to be continued and if anything intensified with its management implications being clearly and specifically identified.

Quantitative population size data for all age groups of several key systems still are needed, as are quantitative habitat use data for these, with careful attention being given to changes with size, day / night, season, spawning, feeding, and refuge (e.g. overwintering) habitats.

The extent and locality of spawning, feeding and refuge migrations need to be carefully defined as well as the precision of homing to these habitats.

2. Limit negative environmental impacts

Present and future impoundment agencies must support effective, well-documented and quantitative compensatory work on the needs listed above and below.

Forest harvesting and associated other road development has high potential for multiple serious impacts which must be addressed before such work starts.

3. Apply promising management practices on grayling populations, habitats and fisheries

There would seem to be no urgent need for grayling hatcheries or stocking except perhaps in a few special cases.

As angling and other pressures mount, even more restrictive angling regulations will be needed. Catch and release fisheries would seem to be the only way to prevent severe stock depletion where angling intensity is high, and the only way to keep large colourful adults in the population. Even such practices may well have harmful sublethal but accumulative effects on populations.

Tests should be made (with adequate before documentation and after evaluation) of stream restoration / enhancement for spawning, rearing and overwintering in two or three key systems.

The one stream fertilization study needs to be well documented statistically and if the apparently promising results obtained so far stand up, extended to a few other key systems.

Where migration route problems are demonstrated, means of improvement / rectification must be used or if necessary developed.

4. Provide public with meaningful opportunities to understand and appreciate grayling

The information available on the successful work in this area by The Grayling Society in the UK, which in little more than a decade has turned the European grayling there from a "coarse" fish to be eradicated into a highly appreciated sport fish, needs to be carefully examined.

Forums, workshops, educational talks and material, and field tours should be provided regularly for the angling public, the resource agency staff, and for developers.

Good luck! It's a challenging task, but "The Lady of the Stream" is counting on you, and is surely more than worthy of the very best efforts!

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LIST OF FIGURE CAPTIONS

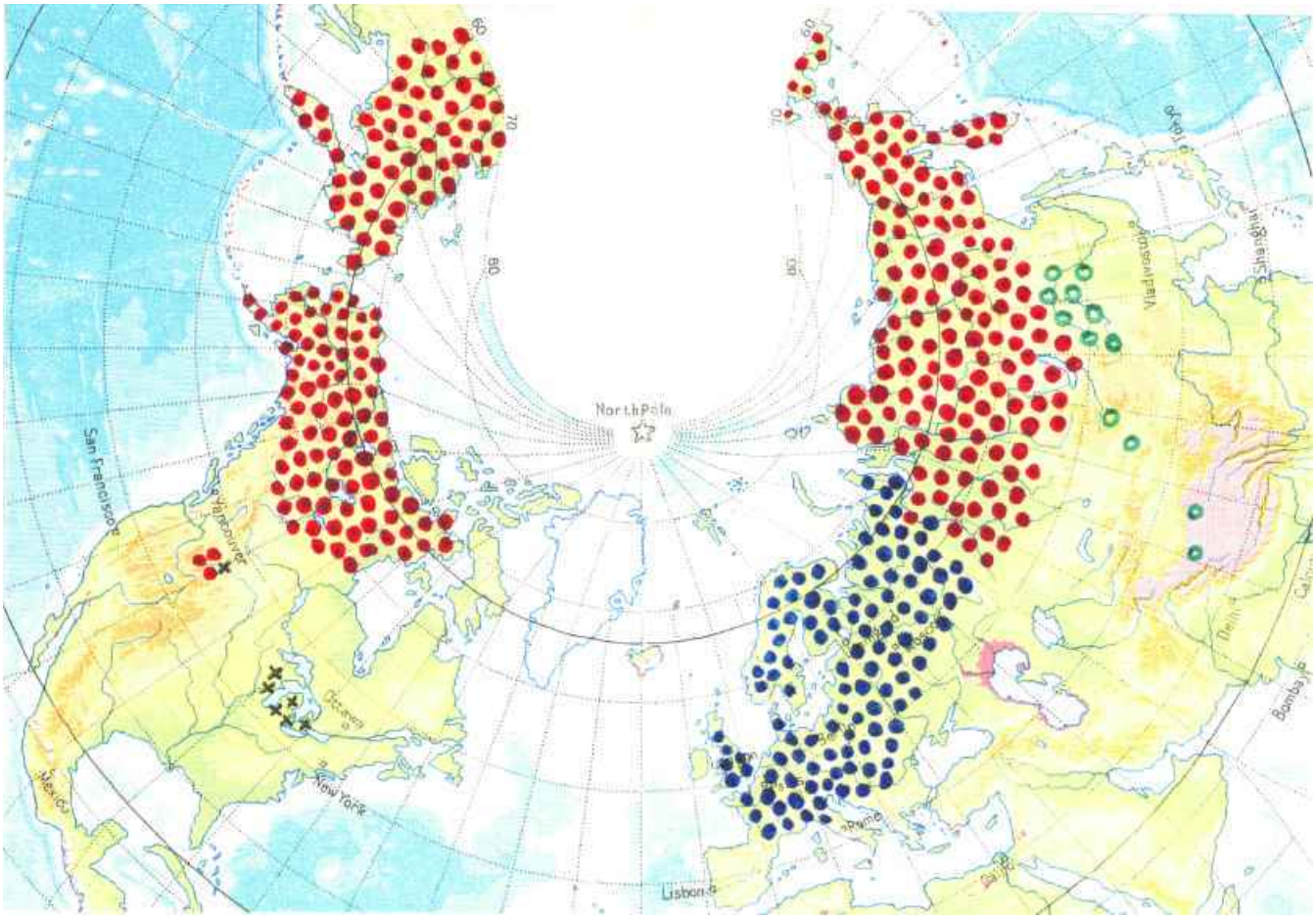
Fig. 1. The generalized world distribution of graylings.

Fig. 2. Annual mean publication rate of scientific papers and technical reports on grayling since the mid 1800s.

Fig. 3. Regional percent partitioning by "species" of 186 recent[a] references on grayling into four broad subject areas using totals above each subject area. References on Arctic grayling separated into North America ans Siberian / Asian contributions.[a] 122 are from 1995 to 1999.

Fig. 4. Regional percent partitioning by "species" of 158 recent references on grayling biology into seven general subject areas. Other details as for Fig. 3.

Fig. 5. Regional percent partitioning by "species" of 46 recent references on grayling management into four general subject areas. Other details as for Fig. 3.



Arctic grayling *Thymallus arcticus*

Extinct populations

European grayling *Thymallus thymallus*

Species status uncertain *Thymallus ?*

FIG. 1

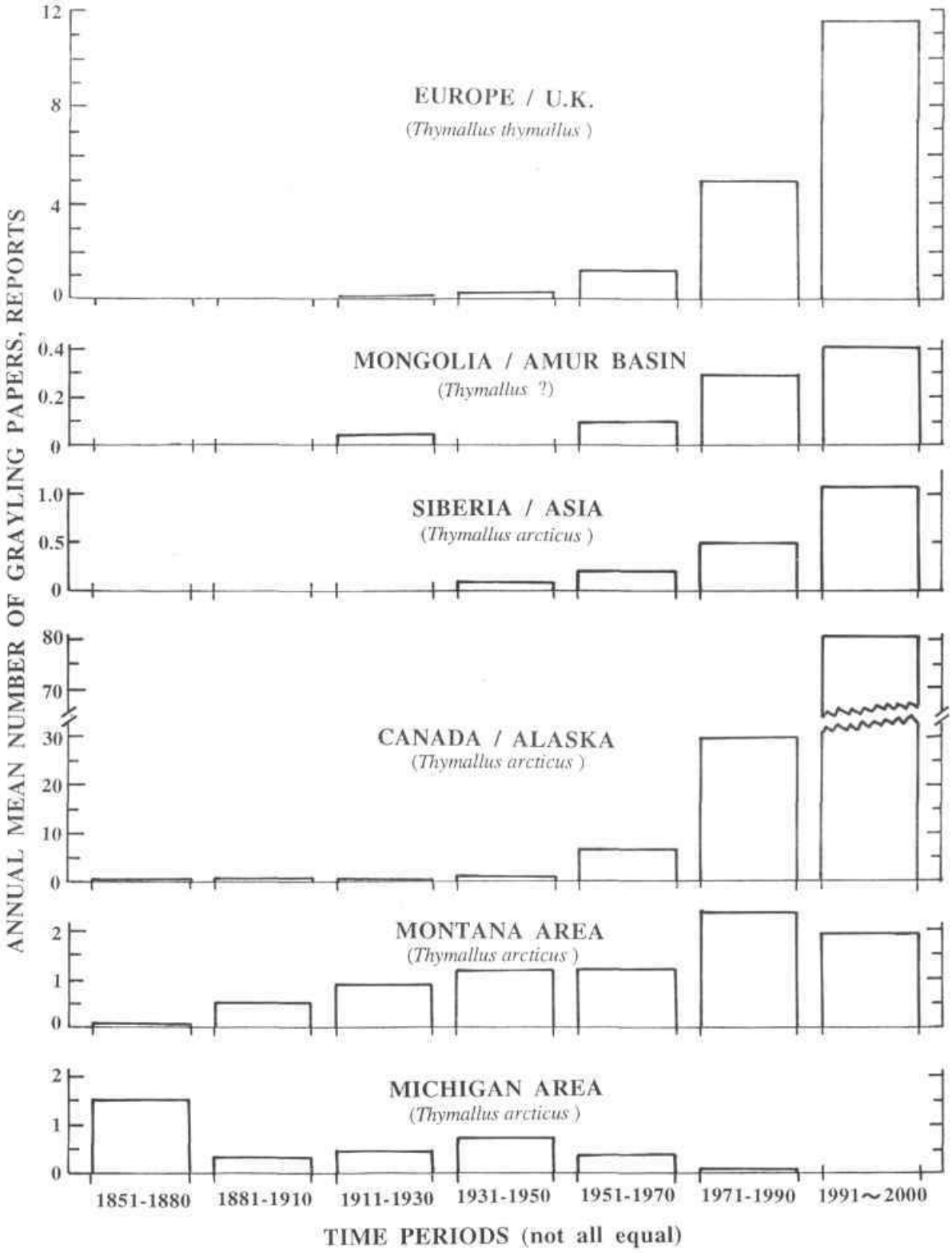

ANNUAL MEAN NUMBER OF GRAYLING PAPERS, REPORTS
EUROPE / U.K.
(Thymallus thymallus)
MONGOLIA / AMUR BASIN
(Thymallus ?)
SIBERIA / ASIA
(Thymallus arcticus)
CANADA / ALASKA
(Thymallus arcticus)
MONTANA AREA
(Thymallus arcticus)
MICHIGAN AREA
(Thymallus arcticus)
12
8
4
0
0.4
0.2
0
1.0
0.5
0
80
70
30
20
10
0
2
1
0
2
1
0
1851-1880
1881-1910
1911-1930
1931-1950
1951-1970
1971-1990
1991~2000
TIME PERIODS (not all equal)

Fig. 2

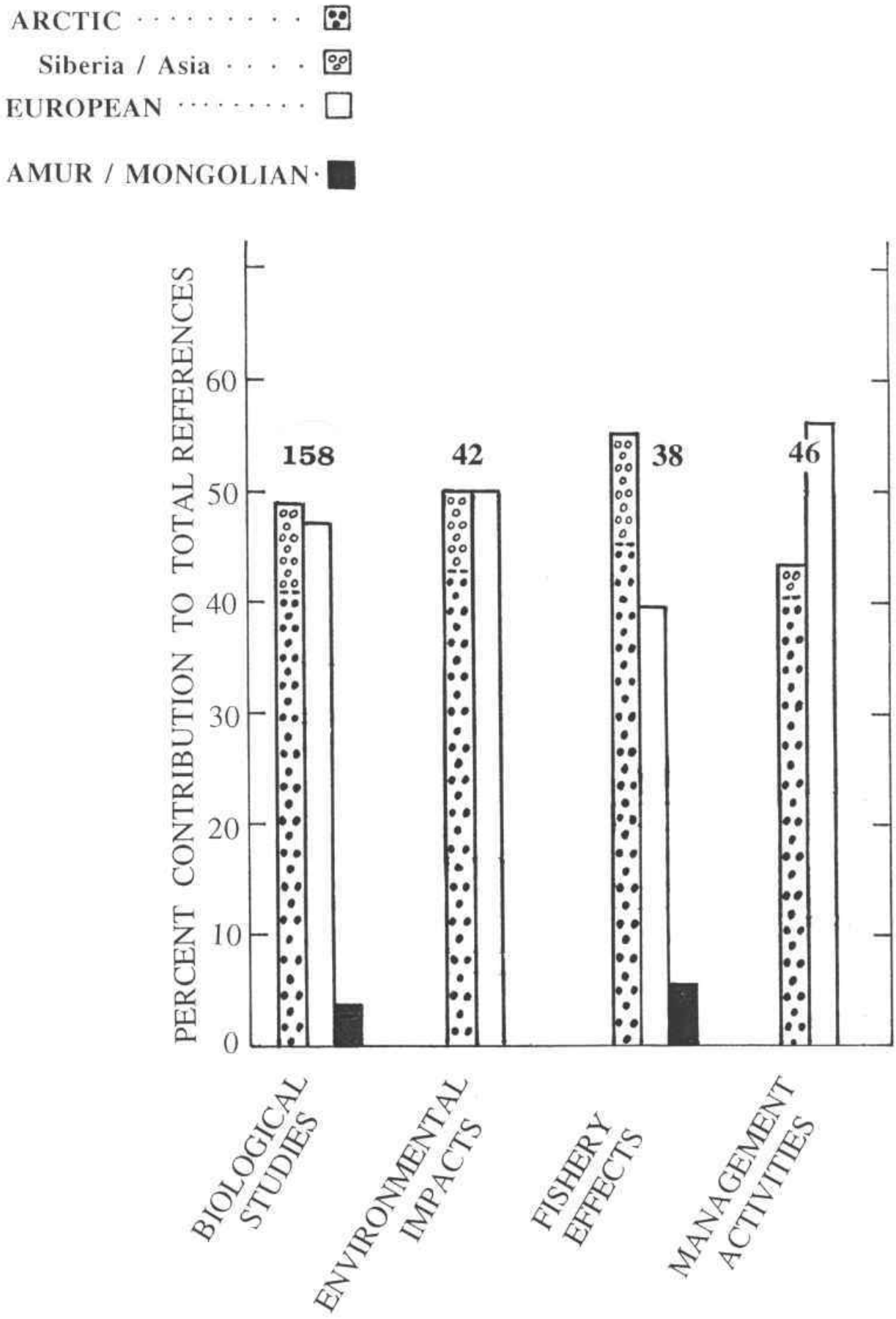

ARCTIC
Siberia / Asia
EUROPEAN
AMUR / MONGOLIAN
PERCENT CONTRIBUTION TO TOTAL REFERENCES
0
10
20
30
40
50
60
158
42
38
46
BIOLOGICAL STUDIES
ENVIRONMENTAL IMPACTS
FISHERY EFFECTS
MANAGEMENT ACTIVITIES

FIG. 3

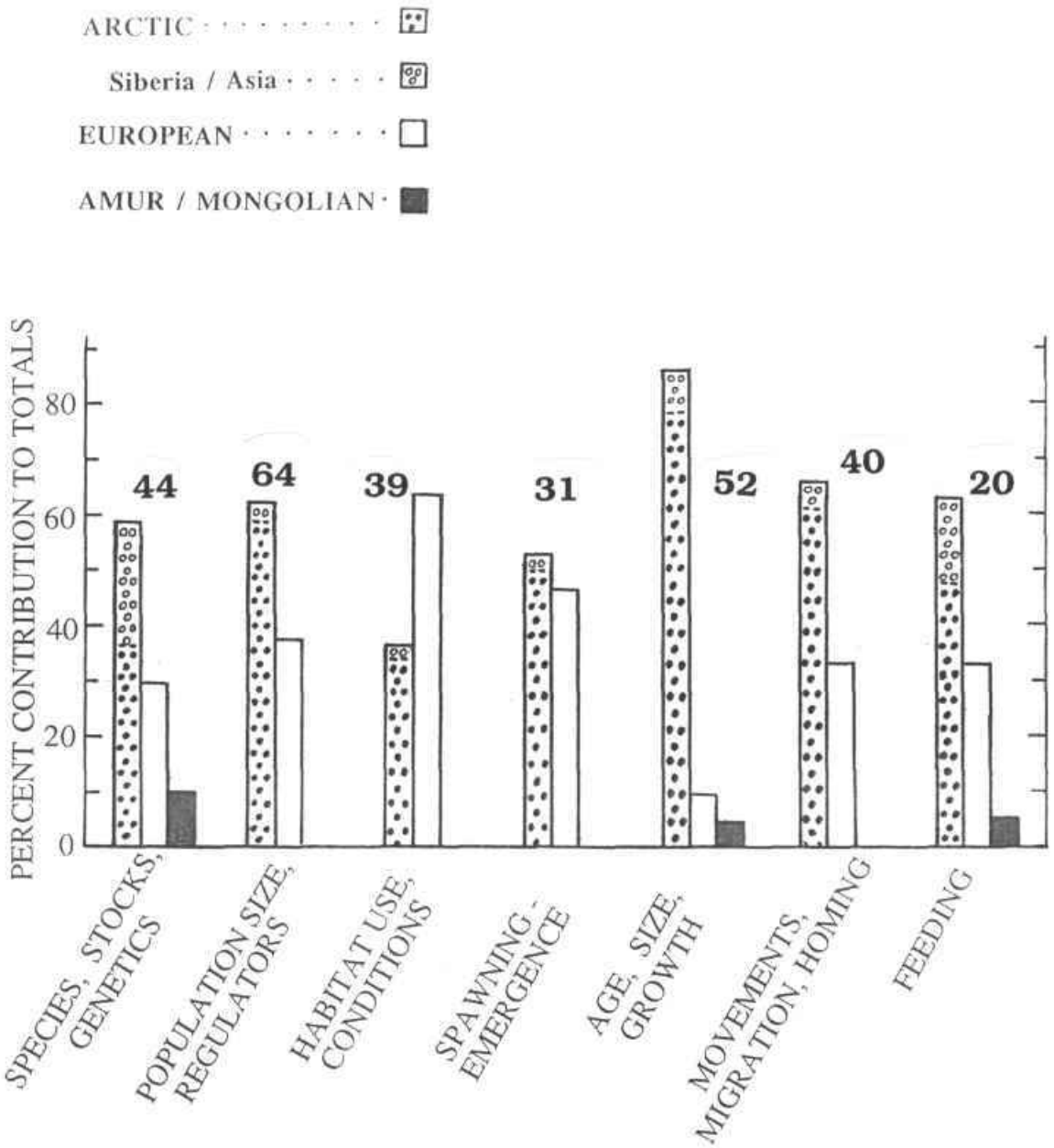

ARCTIC
Siberia / Asia
EUROPEAN
AMUR / MONGOLIAN
PERCENT CONTRIBUTION TO TOTALS
0
20
40
60
80
44
64
39
31
52
40
20
SPECIES, STOCKS, GENETICS
POPULATION SIZE, REGULATORS
HABITAT USE, CONDITIONS
SPAWNING, EMERGENCE
AGE, SIZE, GROWTH
MOVEMENTS, MIGRATION, HOMING
FEEDING

Fig. 4

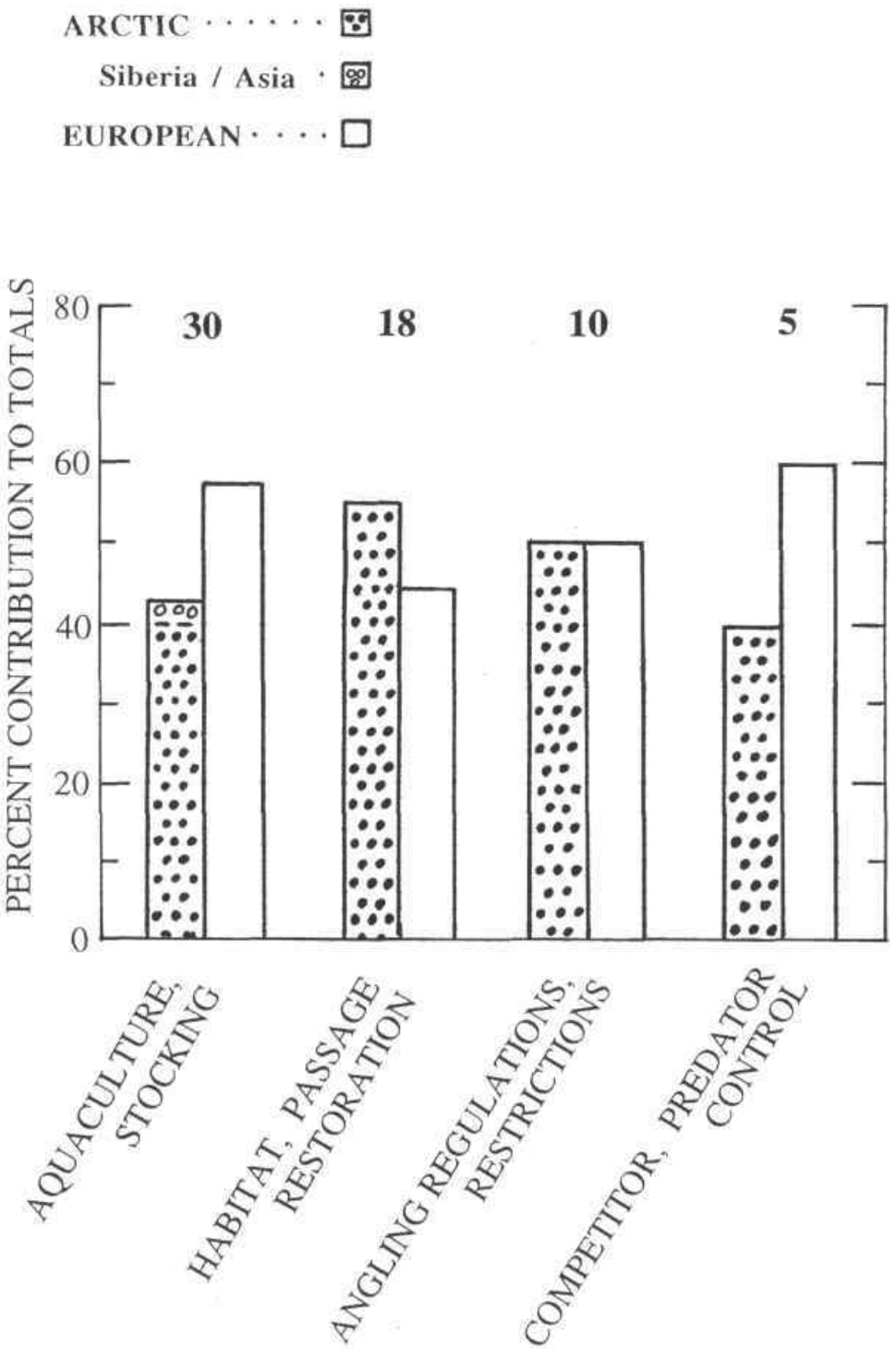

ARCTIC
Siberia / Asia
EUROPEAN
PERCENT CONTRIBUTION TO TOTALS
80
60
40
20
0
30
18
10
5
AQUACULTURE, STOCKING
HABITAT, PASSAGE RESTORATION
ANGLING REGULATIONS, RESTRICTIONS
COMPETITOR, PREDATOR CONTROL

FIG. 5

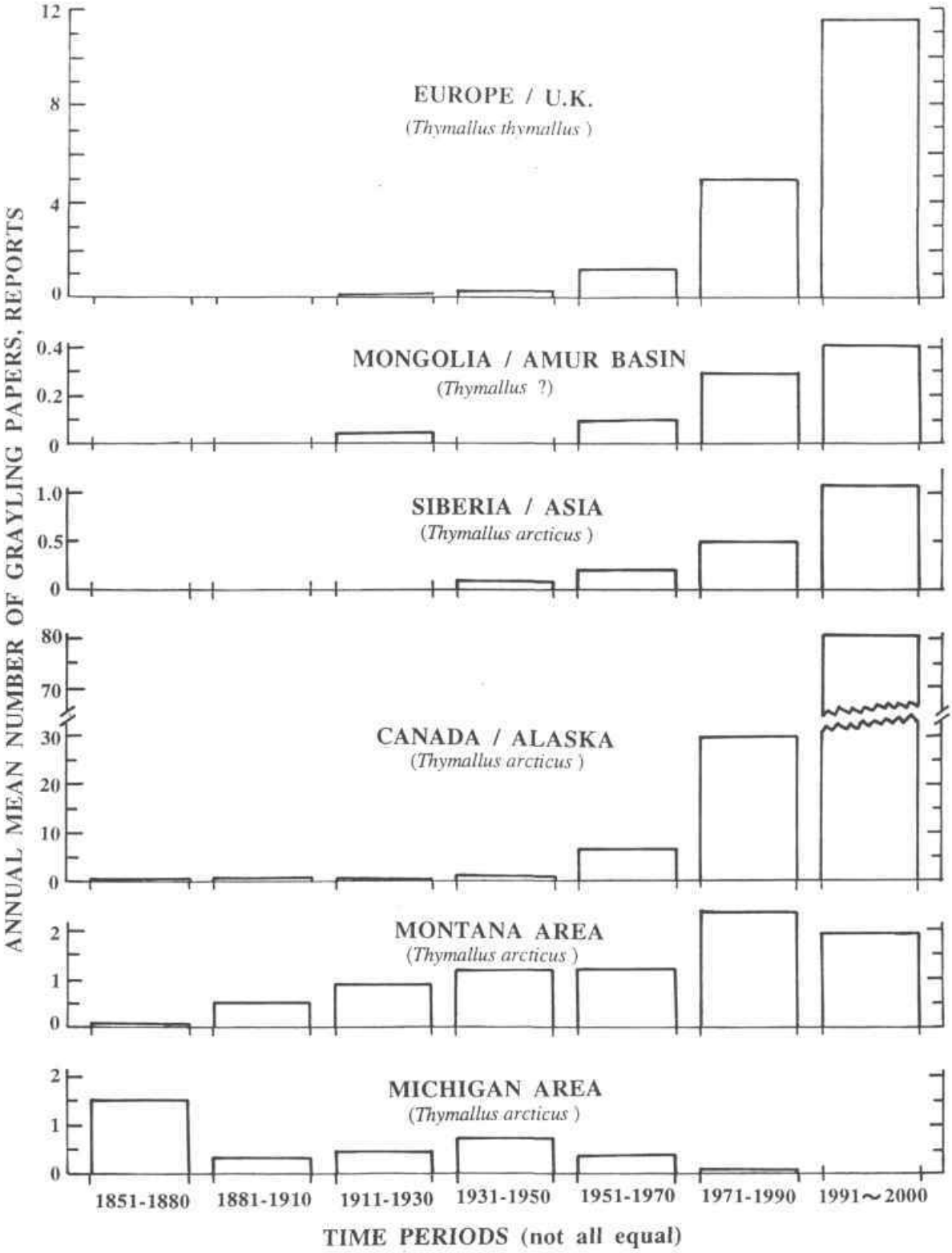

ANNUAL MEAN NUMBER OF GRAYLING PAPERS, REPORTS
EUROPE / U.K.
(Thymallus thymallus)
MONGOLIA / AMUR BASIN
(Thymallus ?)
SIBERIA / ASIA
(Thymallus arcticus)
CANADA / ALASKA
(Thymallus arcticus)
MONTANA AREA
(Thymallus arcticus)
MICHIGAN AREA
(Thymallus arcticus)
1851-1880
1881-1910
1911-1930
1931-1950
1951-1970
1971-1990
1991~2000
TIME PERIODS (not all equal)

Fig. 2

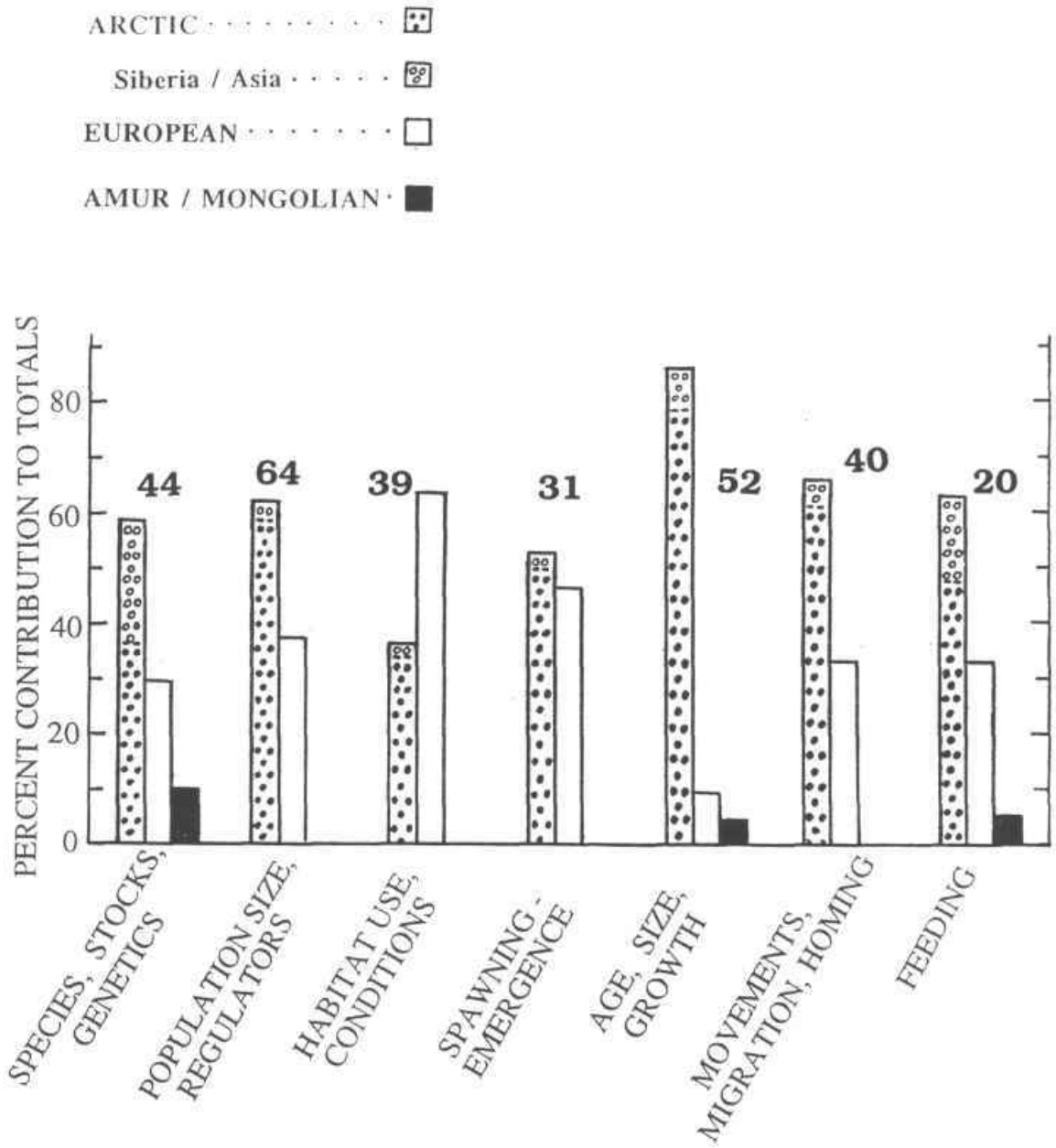
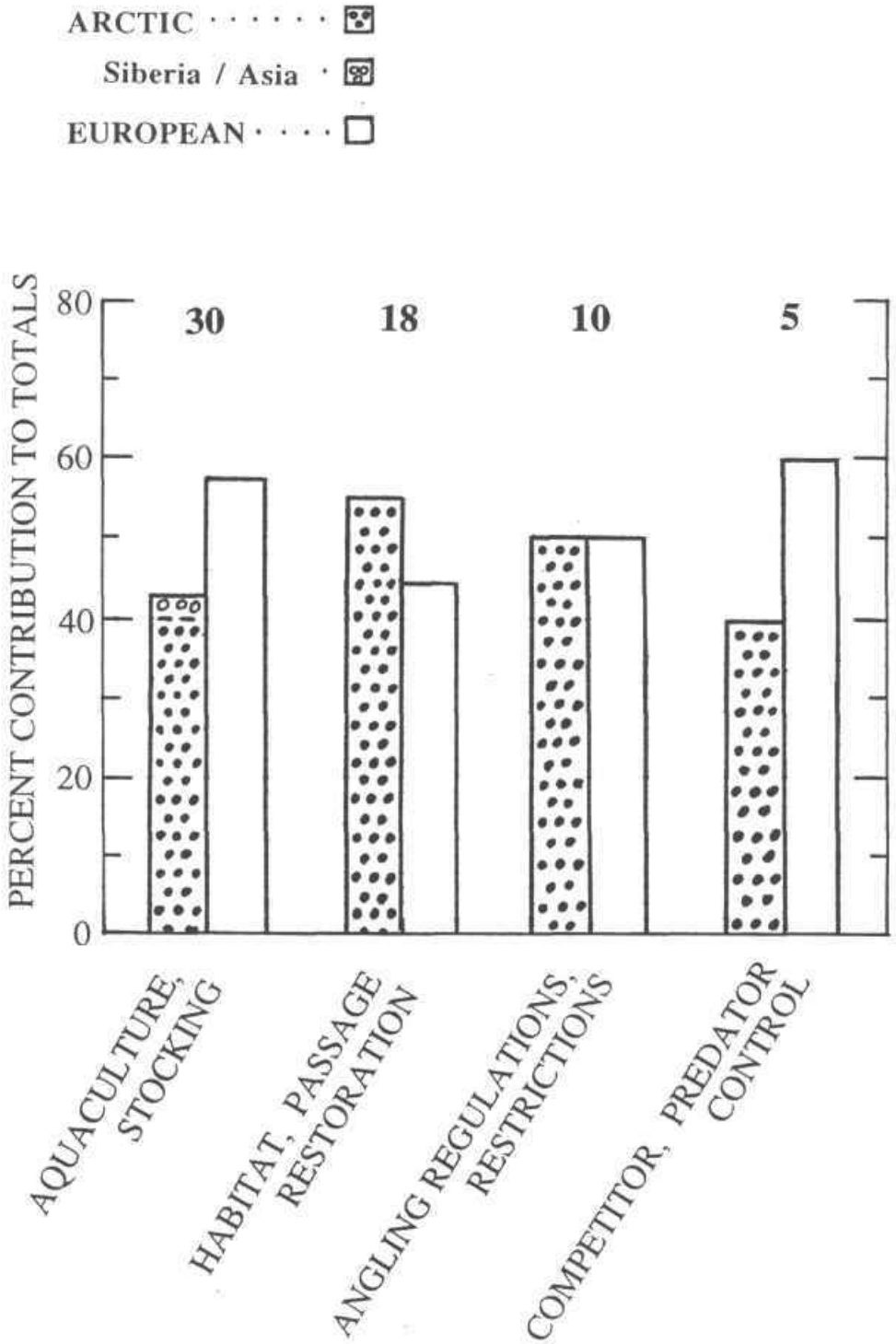

ARCTIC
Siberia / Asia
EUROPEAN
AMUR / MONGOLIAN
PERCENT CONTRIBUTION TO TOTALS
0
20
40
60
80
44
64
39
31
52
40
20
SPECIES, STOCKS, GENETICS
POPULATION SIZE, REGULATORS
HABITAT USE, CONDITIONS
SPAWNING - EMERGENCE
AGE, SIZE, GROWTH
MOVEMENTS, MIGRATION, HOMING
FEEDING

FIG 4


ARCTIC
Siberia / Asia
EUROPEAN
PERCENT CONTRIBUTION TO TOTALS
80
60
40
20
0
30
18
10
5
AQUACULTURE, STOCKING
HABITAT, PASSAGE RESTORATION
ANGLING REGULATIONS, RESTRICTIONS
COMPETITOR, PREDATOR CONTROL