

# Scientific Writing and Editing

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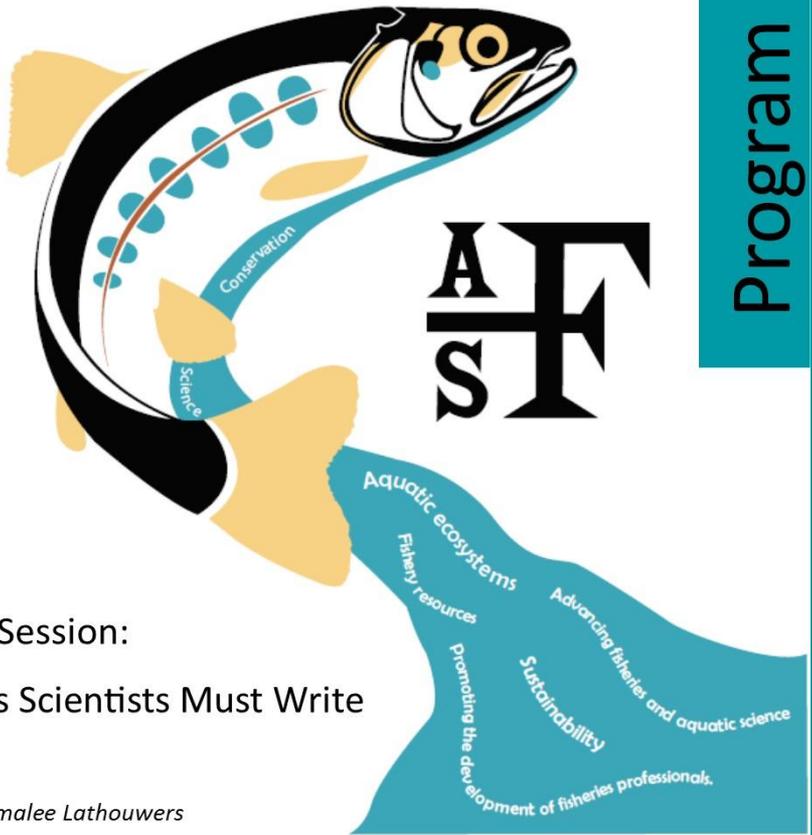
*Hammond Bay Biological Station*



American Fisheries Society

Idaho Chapter

36<sup>th</sup> Annual Meeting  
February 28 - March 2, 2018  
Shilo Inn  
Idaho Falls, Idaho



Program

Plenary Session:  
Fisheries Scientists Must Write

Artwork by Emalee Lathouwers

The poster for the American Fisheries Society Idaho Chapter's 36th Annual Meeting features a central illustration of a fish, likely a salmon, with a blue and yellow color scheme. The fish's body is curved, and it has a large eye. Labels are placed along the fish's body and tail: 'Conservation' and 'Science' are on the side, 'Aquatic ecosystems' and 'Fishery resources' are on the tail, and 'Advancing fisheries and aquatic science', 'Sustainability', and 'Promoting the development of fisheries professionals' are on the tail's fin. The American Fisheries Society (AFS) logo is prominently displayed to the right of the fish. A vertical teal bar on the right side of the poster contains the word 'Program' in white. The top of the poster has a yellow header with the AFS logo and the text 'American Fisheries Society' and 'Idaho Chapter'. The bottom of the poster has a teal footer with the text 'Plenary Session: Fisheries Scientists Must Write' and 'Artwork by Emalee Lathouwers'.

# Writing and Editing Acknowledgments

- Editors of my early publications (teachers):
  - Paul Eschmeyer (USFWS Technical Editor)
  - Bob Kendall (AFS Journals Editor)
- AFS Journals Managers (mentors):
  - Sally Kendall
  - Charlie Moseley
- Former students:
  - Water 483 Undergraduates ( $n = 202$ )
  - Graduate Students ( $n = 29$ )
- Authors of 1,281 NAJFM manuscripts

# Writing and Editing Workshop Format

- Part 1 – Scientific Writing  
(most of the day)
- Part 2 – Scientific Editing  
(last part of the day)

# Scientific Writing

## Preamble

- Understanding is clouded when authors fail to write clearly or organize the manuscript effectively.
  - Reviewers and editors resent authors who fail to prepare their manuscripts carefully and in accordance with journal style guidelines!
  - A possible penalty for poor preparation is angry reviewers and editors, which can result in rejection of the manuscript!

# Scientific Writing

## Preamble

- Authors are responsible for writing their manuscripts to most clearly convey the purpose, conduct, findings, and meaning of their study.
  - Authors must take their responsibility seriously because reviewers are asked to devote their valuable time to the review process.
  - Authors must never “use” the peer review process to develop their manuscripts (due diligence requires attention to detail).

# Scientific Writing

## Preamble

- Two rules every author must recall when dealing with the peer review process:
  - Rule #1 – The editor is always right!
  - Rule #2 – When in doubt, refer to Rule #1!
- “No such thing as immortal prose!”
  - Never take offense with editorial changes.
  - Always remember that you are just trying to tell readers your story as clearly as possible!

# Scientific Writing Outline

- Clarity
  - Word choices
  - Sentence structure
  - Paragraph structure
  - Section organization
  - Manuscript order
- Content
  - Title
  - Abstract
  - Introduction
  - Methods
  - Results
  - Discussion
  - Tables
  - Figures

# Scientific Writing

## Clarity

- Word choices →
  - Sentence structure →
    - Paragraph organization →
      - Section organization →
        - Manuscript order →
- *Do all parts of the manuscript build consistently from one to another?*

# Scientific Writing

## Word Problems

- Accuracy – Use definitive nouns and verbs, rather than ambiguous pronouns, or neutral or ambiguous verbs.
  - Pronouns form very weak openings to sentences.
  - Never begin a sentence or phrase with “it” or “there” (*English 101*).
    - “It” obscures the subject of the sentence.
    - “There” invariably results in an inverted sentence.
  - Avoid jargon (e.g. “aged” and “aging” do not mean what you intend!)

# Scientific Writing

## Word Problems

- Accuracy – Use definitive nouns and verbs, rather than ambiguous pronouns, or neutral or ambiguous verbs.
  - Neutral verbs convey nothing about the direction of the contrast.
  - “Differed” says nothing about the direction of change or difference.
  - “Improved” is value laden, so may have many meanings.

# Scientific Writing

## Word Problems

- Precision – Avoid using nonessential words, usually adjectives, adverbs or articles, that add little to the point of the sentence.
  - Adjectives are usually not necessary to convey your intended meaning.
  - Adjectives are confusing when strung together, so better to separate modifiers.

# Scientific Writing

## Word Problems

- Precision – Avoid using nonessential words, usually adjectives, adverbs or articles, that add little to the point of the sentence.
  - Adverbs are usually not necessary to convey your intended meaning.
  - For example, “very” or “usually” require further definition, so better to just use explicit terms.
    - “Very” = How much?
    - “Usually” = How often?

# Scientific Writing

## Word Problems

- Precision – Avoid using nonessential words, usually adjectives, adverbs or articles, that add little to the point of the sentence.
  - “The” singular definite article is “the” most misused word in “the” English language.
  - If the modified noun is neither singular nor definite, “the” should not be used.
  - Let’s say this another way: “The” is incorrect when the modified noun is either plural or indefinite.

# Scientific Writing

## Sentence Problems

- Order – Hiding the subject at the end, not the beginning, of the sentence (inverted = *Yoda Speak*: “*A perimeter around the Jedi Knights we will form*”).
  - Bad – There was no significant difference in growth of largemouth bass after imposition of the minimum length limit in West Blue Lake.
  - Good – Growth of largemouth bass did not change significantly after imposition of the minimum length limit in West Blue Lake.

# Scientific Writing

## Sentence Problems

- Parallelism – Stating comparative clauses and sentences in nonparallel form.
  - Bad – Before the regulation change, growth varied erratically, but increased after the regulation change.
  - Good – Growth varied erratically before the regulation change, but increased after the regulation change.

# Scientific Writing

## Sentence Problems

- Voice – Leading off the sentence with “who” when “what” is important (e.g. “we” or names).
  - “Who” is unimportant when describing what was done (Methods), so thank those who participated in the Acknowledgments.
  - “Who” is unimportant when describing what was found (Introduction or Discussion), so attribute findings to authors (at the end of the sentence).
  - Leading off with “who” often pushes the subject to the end of the sentence (buried or inverted).

# Scientific Writing

## Sentence Problems

- Voice – Leading off the sentence with “who” when “what” is important (“we”).
  - Bad – Schill et al. (2017) found that eradication of nonnative Brook Trout populations was difficult to achieve with standard techniques, such as electrofishing removal or piscicides.
  - Good – Eradication of nonnative Brook Trout populations was difficult to achieve with standard techniques, such as electrofishing removal or piscicides (Schill et al. (2017)).

# Scientific Writing

## Sentence Problems

- Voice – Lead off the sentence with “who” ***only*** when attribution is essential (i.e. conclusions).
  - Bad – Eradication of nonnative Brook Trout is impossible when using electrofishing or piscicides (Schill et al. (2017)).
  - Good – Schill et al. (2017) concluded that eradication of nonnative Brook Trout is impossible when using electrofishing or piscicides.

# Scientific Writing

## Paragraph Problems

- Organize each paragraph using a topic sentence format.
  - Begin each paragraph with a sentence that describes the overall topic of the paragraph.
  - Continue each paragraph with sentences that describe details of the topic.

# Scientific Writing

## Paragraph Problems

- Common Problem – Describing mixed topics in a paragraph.
  - Limit each paragraph to a single topic that is declared in the first (topic) sentence.
  - Presenting mixed topics confuses readers and thereby hinders understanding.

# Scientific Writing

## Section Problems

- Sections are essays, so paragraphs should communicate the purpose of the essay.
  - Introduction = motivate your study objectives.
  - Methods = describe how you conducted your study.
  - Results = describe what you found.
  - Discussion = integrate your findings with other relevant knowledge.

# Scientific Writing

## Section Problems

- Common Problem – lack of logical order of paragraphs.
  - Introduction = begin broadly (scientific and geographic scope) and then narrow the topic.
  - Methods = describe the conduct of the study in chronological order.
  - Results = describe each primary finding in a separate paragraph.
  - Discussion = discuss each primary finding in a separate paragraph.

# Scientific Writing

## Manuscript Problems

- Parallelism – Use a parallel order of topics among sections.
  - Introduce the study objectives (topics) in a logical sequence.
  - Follow the same sequence of topics in the Methods, Results, and Discussion.
  - Ensures that you address the study objectives, which is a common problem in many articles.

# Scientific Writing

## Content

- Title
- Abstract
- Introduction
- Methods
- Results
- Discussion
- Tables
- Figures

# Tugging on Superman's cape!

## Evaluation of an Unsuccessful Brook Trout Electrofishing Removal Project in a Small Rocky Mountain Stream

KEVIN A. MEYER,\* JAMES A. LAMANSKY, JR., AND DANIEL J. SCHILL

*Idaho Department of Fish and Game, 1414 East Locust Lane, Nampa, Idaho 83686, USA*

*Abstract.*—In the western United States, exotic brook trout *Salvelinus fontinalis* frequently have a deleterious effect on native salmonids, and biologists often attempt to remove brook trout from streams by means of electrofishing. Although the success of such projects typically is low, few studies have assessed the underlying mechanisms of failure, especially in terms of compensatory responses. A multiagency watershed advisory group (WAG) attempted to remove brook trout from a stream to protect and enhance native salmonids in 7.8 km<sup>2</sup> of stream. Although the project was successful in suppressing brook trout abundance and increasing the abundance of native salmonids, increased natural mortality, increased abundance of age-0 brook trout, and increased abundance of age-1 and older brook trout removed was 1,101 in 1998, 1,211 in 1999, and 670 in 2000; removal constituted an estimated 88% of the total number of brook trout in the stream in 1999 and 79% in 2000. Although abundance of age-1 and older brook trout declined slightly during and after the removals, abundance of age-0 brook trout increased 789% in the entire stream 2 years after the removals ceased. Total annual survival rate for age-2 and older brook trout did not decrease during the removals, and the removals failed to produce an increase in the abundance of native redband trout *Oncorhynchus mykiss gairdneri*. Lack of a meaningful decline and unchanged total mortality for older brook trout during the removals suggest that a compensatory response occurred in the brook trout population via reduced natural mortality, which offset the removal of large numbers of brook trout. Although we applaud WAG personnel for their goal of enhancing native salmonids by suppressing brook trout via electrofishing removal, we conclude that their efforts were unsuccessful and suggest that similar future projects elsewhere over such large stream lengths would be costly, quixotic enterprises.

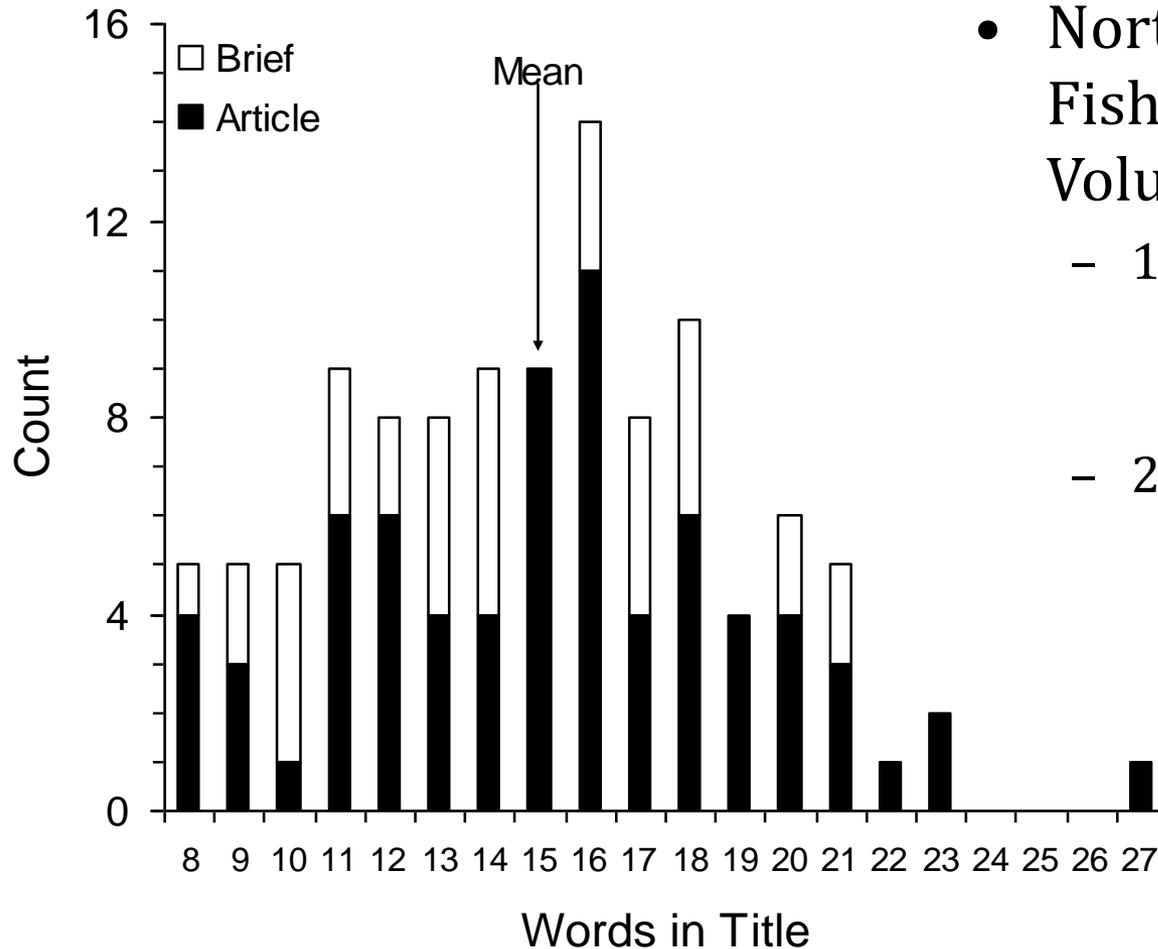
58 Google Citations  
31 Web of Science Citations

# Scientific Writing

## Title

- The title is read by more individuals than any other part of the manuscript, so must be carefully crafted (*short and sweet*).
- Write the title first, and then review each word for accuracy and precision:
  - Does the title accurately reflect the focus and content of the paper (word choice)?
  - Is the title stated precisely, preferably in 12 words or less (every word matters)?

# Scientific Writing Title



- North American Journal of Fisheries Management, Volume 26 (Issues 1 – 4):
  - 109 Titles
    - 73 Articles
    - 36 Management Briefs
  - 29% of Titles  $\leq$  12 Words
    - 27% for Articles
    - 33% for Briefs

# Scientific Writing Title

- Longest original title = 27 words:
  - A Bayesian Analysis of Biological Uncertainty for a Whole-Lake Fertilization Experiment for Sockeye Salmon in Chilko Lake, British Columbia, and Implications for the Benefit-Cost Ratio

# Scientific Writing

## Title

- Longest original title = 27 words:
  - A Bayesian Analysis of Biological Uncertainty for a Whole-Lake Fertilization Experiment for Sockeye Salmon in Chilko Lake, British Columbia, and Implications for the Benefit-Cost Ratio
- Revised title = 12 words:
  - Biological Uncertainty of Fertilization for Sockeye Salmon in Chilko Lake, British Columbia

# Scientific Writing Title

- Original title = 15 words:
  - Evaluation of an Unsuccessful Brook Trout Electrofishing Removal Project in a Small Rocky Mountain Stream

# Scientific Writing Title

- Original title = 15 words:
  - Evaluation of an Unsuccessful Brook Trout Electrofishing Removal Project in a Small Rocky Mountain Stream
- Revised title = 12 words:
  - Attempted Electrofishing Removal of Brook Trout in a Second-Order Idaho Stream

# Scientific Writing Title

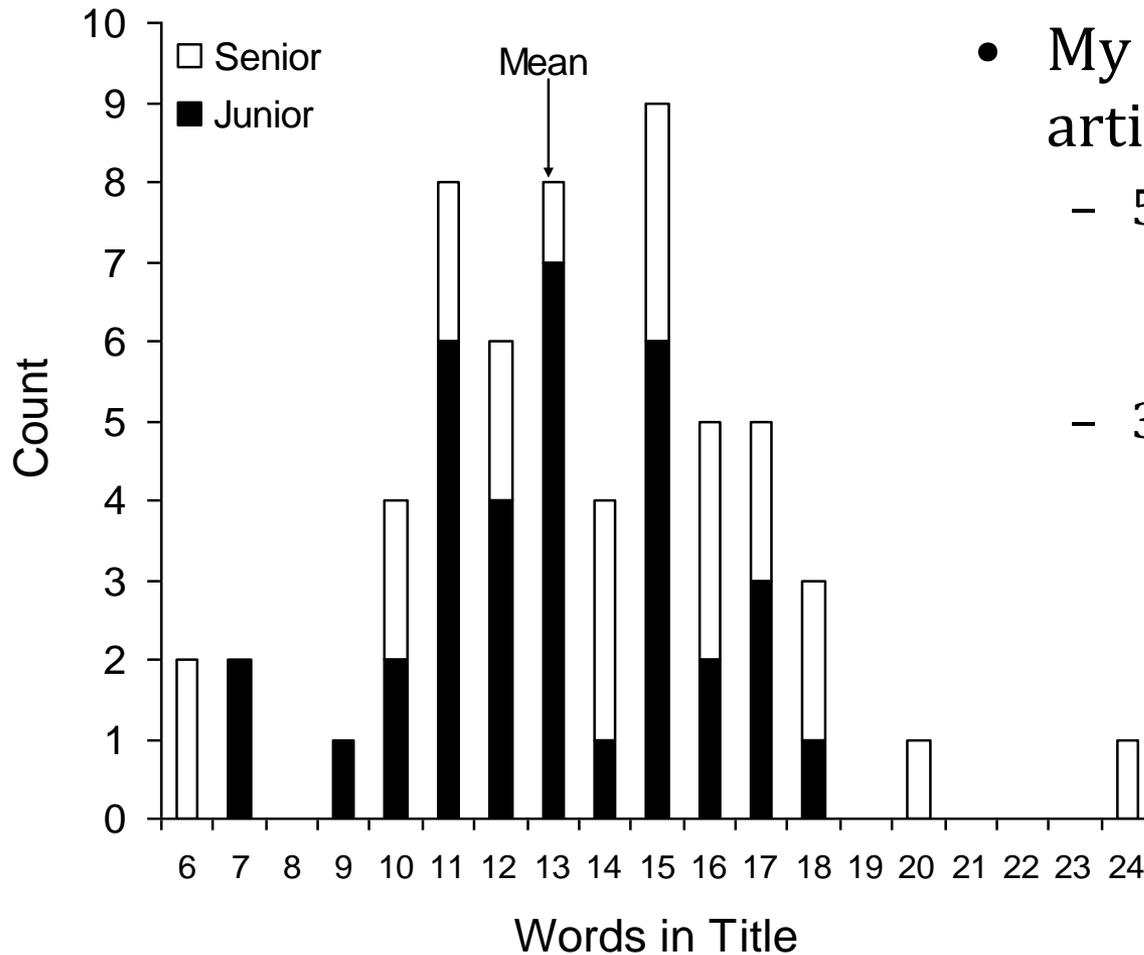
- Original title = 15 words:
  - Spawning Demographics and Juvenile Dispersal of an Adfluvial Bull Trout Population in Trestle Creek, Idaho

# Scientific Writing

## Title

- Original title = 15 words:
  - Spawning Demographics and Juvenile Dispersal of an Adfluvial Bull Trout Population in Trestle Creek, Idaho
- Revised title = 13 words:
  - Adult Demographics and Juvenile Dispersal of Adfluvial Bull Trout in Trestle Creek, Idaho

# Scientific Writing Title



- My own peer-reviewed articles in 14 outlets:
  - 59 Titles
    - 24 as senior author
    - 35 as junior author
  - 39% of Titles  $\leq$  12 Words
    - 33% as senior author
    - 43% as junior author

# Scientific Writing Title

- My longest original title = 24 words:
  - A Method for Correcting the Relative Weight ( $W_r$ ) Index for Seasonal Patterns in Relative Condition ( $K_n$ ) with Length as Applied to Walleye in Wisconsin

# Scientific Writing Title

- My longest original title = 24 words:
  - A Method for Correcting the Relative Weight ( $W_r$ ) Index for Seasonal Patterns in Relative Condition ( $K_n$ ) with Length as Applied to Walleye in Wisconsin
- Revised title = 12 words:
  - Correcting for Seasonal Length-Related Trends in Relative Weight ( $W_r$ ) of Walleye
- *I am a sinner, but I can learn to do better!*

# Scientific Writing

## Abstract

- Why did you do the study?
- How did you do your study?
- What did you find?
- What do your findings mean?

# Scientific Writing

## Abstract

- Why did you do the study?
  - 1<sup>st</sup> sentence (may be combined with 2<sup>nd</sup>).
  - Copy objective(s) from Introduction.
  - Do not need to rationalize the objective.
- How did you do your study?
  - 2<sup>nd</sup> sentence (may be combined with 1<sup>st</sup>).
  - Cannot copy from text, so integrate from text.
  - Describe only the general approach (no details).

# Scientific Writing

## Abstract

- What did you find?
  - Forms main body of abstract.
  - Copy topic statements of results from text.
  - Devote one sentence to each major finding.
- What do your findings mean?
  - Last sentence of abstract.
  - Copy the primary conclusion from the text.
  - What is your single, most-important conclusion?

# Scientific Writing

## Abstract

Original abstract (305 words) – In the western United States, exotic brook trout *Salvelinus fontinalis* frequently have a deleterious effect on native salmonids, and biologists often attempt to remove brook trout from streams by means of electrofishing. Although the success of such projects typically is low, few studies have assessed the underlying mechanisms of failure, especially in terms of compensatory responses. A multiagency watershed advisory group (WAG) conducted a 3-year removal project to reduce brook trout and enhance native salmonids in 7.8 km of a southwestern Idaho stream. **We evaluated the costs and success of their project in suppressing brook trout and looked for brook trout compensatory responses, such as decreased natural mortality, increased growth, increased fecundity at length, and earlier maturation.** The total number of brook trout removed was 1,401 in 1998, 1,241 in 1999, and 890 in 2000; removal constituted an estimated 88% of the total number of brook trout in the stream in 1999 and 79% in 2000. Although abundance of age-1 and older brook trout declined slightly during and after the removals, abundance of age-0 brook trout increased 789% in the entire stream 2 years after the removals ceased. Total annual survival rate for age-2 and older brook trout did not decrease during the removals, and the removals failed to produce an increase in the abundance of native redband trout *Oncorhynchus mykiss gairdneri*. **Lack of a meaningful decline and unchanged mortality for older brook trout during the removals suggest that a compensatory response occurred in the brook trout population via reduced natural mortality, which offset the removal of large numbers of brook trout. Although we applaud WAG personnel for their goal of enhancing native salmonids by suppressing brook trout via electrofishing removal, we conclude that their efforts were unsuccessful and suggest that similar future projects elsewhere over such large stream lengths would be costly, quixotic enterprises.**

# Scientific Writing

## Abstract

### Why did you do your study?

- Original (83 words) – In the western United States, exotic brook trout *Salvelinus fontinalis* frequently have a deleterious effect on native salmonids, and biologists often attempt to remove brook trout from streams by means of electrofishing. Although the success of such projects typically is low, few studies have assessed the underlying mechanisms of failure, especially in terms of compensatory responses. A multiagency watershed advisory group (WAG) conducted a 3-year removal project to reduce brook trout and enhance native salmonids in 7.8 km of a southwestern Idaho stream. **[Overlaps with next part.]**
- Revised (18 words) – To determine if non-native brook trout *Salvelinus fontinalis* could be eradicated from a small Idaho stream using electrofishing, ... **[connect to next part...]**

# Scientific Writing

## Abstract

### How did you do your study?

- Original (34 words) – We evaluated the costs and success of their project in suppressing brook trout and looked for brook trout compensatory responses, such as decreased natural mortality, increased growth, increased fecundity at length, and earlier maturation. **[Overlaps with previous part.]**
- Revised (24 words) – ... we quantified abundance and compensatory responses of brook trout to three years of intensive electrofishing removals in 7.8 km of a southwestern Idaho stream.

# Scientific Writing

## Abstract

### What did you find?

- Original (105 words) – The total number of brook trout removed was 1,401 in 1998, 1,241 in 1999, and 890 in 2000; removal constituted an estimated 88% of the total number of brook trout in the stream in 1999 and 79% in 2000. Although abundance of age-1 and older brook trout declined slightly during and after the removals, abundance of age-0 brook trout increased 789% in the entire stream 2 years after the removals ceased. Total annual survival rate for age-2 and older brook trout did not decrease during the removals, and the removals failed to produce an increase in the abundance of native redband trout *Oncorhynchus mykiss gairdneri*.
- Revised (76 words) – Total numbers of brook trout removed were 1,401 in 1998, 1,241 in 1999, and 890 in 2000. Removals were about 88% of total numbers in 1999 and 79% in 2000. After removals, abundance of age-1 and older brook trout declined slightly, whereas abundance of age-0 brook trout increased 789%. Total annual survival of age-2 and older brook trout did not decrease after removals. Abundance of native redband trout *Oncorhynchus mykiss gairdneri* failed to increase after removals.

# Scientific Writing

## Abstract

### What do your findings mean?

- Original (83 words) – Lack of a meaningful decline and unchanged mortality for older brook trout during the removals suggest that a compensatory response occurred in the brook trout population via reduced natural mortality, which offset the removal of large numbers of brook trout. Although we applaud WAG personnel for their goal of enhancing native salmonids by suppressing brook trout via electrofishing removal, we conclude that their efforts were unsuccessful and suggest that similar future projects elsewhere over such large stream lengths would be costly, quixotic enterprises.
- Revised (24 words) – We conclude that compensatory reductions in annual natural mortality offset intensive electrofishing removals of brook trout and thereby prevented enhancement of native redband trout.

# Scientific Writing

## Abstract

Revised Abstract (142 words) – To determine if non-native brook trout *Salvelinus fontinalis* could be eradicated from a small Idaho stream using electro-fishing, we quantified abundance and compensatory responses of brook trout to three years of intensive electrofishing removals in 7.8 km of a southwestern Idaho stream. Total numbers of brook trout removed were 1,401 in 1998, 1,241 in 1999, and 890 in 2000. Removals were about 88% of total numbers in 1999 and 79% in 2000. After removals, abundance of age-1 and older brook trout declined slightly, whereas abundance of age-0 brook trout increased 789%. Total annual survival of age-2 and older brook trout did not decrease after removals. Abundance of native redband trout *Oncorhynchus mykiss gairdneri* failed to increase after removals. We conclude that compensatory reductions in annual natural mortality offset intensive electrofishing removals of brook trout and thereby prevented enhancement of native redband trout. ***A 53% reduction in words!***

# Scientific Writing

## Introduction

- Motivate the study broadly enough for the journal's audience.
  - Describe the background for the objectives at the appropriate geographic and scientific scale for the journal.
  - See the journal's title and reviewer guidelines to diagnose the journal's scope.
  - For example, North American Journal of Fisheries Management.

# Scientific Writing

## Introduction

- Clearly and succinctly describe the rationale, without extraneous details.
  - Does the introduction go too far in reviewing the subject area, rather than succinctly motivating the objectives?
  - Include one paragraph for each element of the argument in support of your objectives.

# Scientific Writing

## Introduction

- Are the objectives stated in terms of what they wished to learn (not what they did!)?
  - Bad – Our objective was to quantify mortality of largemouth bass in West Blue Lake.
  - Good – Our objective was to determine if total annual mortality on largemouth bass was too high in West Blue Lake.

# Scientific Writing

## Introduction

Introduced fish species that establish self-sustaining populations threaten the long-term persistence of native fishes (Moyle 1986; Allan and Flecker 1993; Rahel 2000). A classic example is the brook trout *Salvelinus fontinalis*, which has been introduced since the late 1800s to diversify or supplement sportfishing opportunities. Brook trout have become widely established in every state in the western United States (Fuller et al. 1999), usually to the detriment of native salmonids (Krueger and May 1991; Young 1995; Levin et al. 2002; see review in Dunham et al. 2002). The ability of brook trout to displace native salmonids is evident, but the mechanisms for their success remain relatively unknown (Fausch 1988, 1989; Griffith 1988; but see Peterson et al. 2004a).

- Topic: Brook trout misbehave when introduced into western streams!
- *An excellent example of an opening paragraph!*

# Scientific Writing

## Introduction

Because of these detrimental effects, biologists have focused their efforts on removing brook trout for conservation and restoration of native salmonids. The most common methods for removing nonnative, stream-dwelling salmonids have been electrofishing (e.g., Moore et al. 1983; Thompson and Rahel 1996; Kulp and Moore 2000; Shepard et al. 2002) and toxicants (e.g., Phinney 1975; Gresswell 1991), although selective angling (Larson et al. 1986; Paul et al. 2003) and trapping (Young et al. 2003) have been used as well. In general, removal projects have met with little success. Meronek et al. (1996) reviewed 250

For example, undesirable fish species were reduced or eliminated in only 50% of 250 fish control projects reviewed by Meronek et al. (1996).

the lack of alternatives to removal and the need to contain exotics such as brook trout compel many biologists to continue implementing fish control projects (Finlayson et al. 2005).

- Topic: Brook trout are often removed to enhance native species, but with little success!
- *A good paragraph, but the topic of limited success is not in the topic sentence!*

# Scientific Writing

## Introduction

Because toxicants (e.g., rotenone and antimycin) kill nontarget species, biologists often view electrofishing as a more desirable alternative for fish removal. However, electrofishing has many of its own shortcomings. First, complete removal of the target species

For example, brook trout were not eradicated from three Wyoming streams despite removing 73–100% of age-0 and 59–100% of age-1 and older fish (Thompson and Rahel 1996).

have eradicated nonnative trout but at tremendous cost for very small (e.g., 0.8–3.0 km) stream sections (Kulp and Moore 2000; Shepard et al. 2002). Another difficulty is that mobile species, such as brook trout, recolonize rapidly unless a barrier between treated and untreated reaches is established. Phinney (1975) found

For example, brook trout repopulated a stream section within one year of its treatment with rotenone (Phinney 1975). Similarly, immigration replaced 40–100% of adult brook trout that were removed in the previous year (Peterson et al. 2004a).

- Topic: Electro-fishing is often used as a control method, but eradication is difficult!
- *A good paragraph, but references focus on authors, rather than findings!*

Even when barriers are established, suppressed populations of brook trout often recover quickly because they mature earlier than most other salmonids.

For example, severe reduction (not elimination) of brook trout by rotenone failed to alter growth because abundance recovered to pre-treatment levels within two years (Cooper et al. 1962).

and, within 2 years, was no different than before the treatment (most fish were age 0 or 1). Furthermore, any remaining or recolonizing brook trout in a treated

Further, brook trout that remain or colonize a treated stream may compensate at lower density through reduced mortality or increased recruitment to restore the population to its original density (McFadden 1977).

rates as a population declines (it can also be the opposite). The effect is to (1) stabilize the population before it is extirpated or (2) restore the population to its original condition (McFadden 1977). In the simplest terms, such changes often stem from a reduction in competition for food or space. Previous studies have indicated that brook trout may compensate for increased exploitation through a variety of methods, including decreased natural mortality (McFadden 1961), increased growth and recruitment (Donald and Alger 1989), and increased age-specific fecundity (Jensen 1971). Because these and other mechanisms are not mutually exclusive and may interact at a variety of life history stages, only a few may be statistically verifiable at any given period of observation (McFadden 1977).

# Scientific Writing

## Introduction

- Topic: Brook trout compensate for reduced density, and thereby negate effects of control programs.
- *A good paragraph, but much too wordy!*

# Scientific Writing

## Introduction

In this paper, we describe an electrofishing removal project that was initiated and conducted by a local watershed advisory group (WAG) in southwestern Idaho. The goal of their project was to eliminate or

Our objectives were to determine if: (1) 3 years of electrofishing removal could eliminate brook trout; and (2) brook trout would compensate for their removal from Pike's Fork, a second-order stream in southwestern Idaho. The goal of brook trout removal was to protect native redband trout *Oncorhynchus mykiss gairdneri* and bull trout *S. confluentus*. However, bull trout were nearly eliminated from the stream before brook trout removal began. Therefore, we quantified the abundance and population dynamics of brook trout and redband trout over the 3-year period.

electrofishing removals by the WAG could eliminate or suppress brook trout and increase abundance of native salmonids in subsequent years and (2) whether brook trout that evaded capture underwent any detectable compensatory responses.

- Topic: To determine if: (1) 3 years of electro-fishing removal could eliminate brook trout; and (2) brook trout would compensate for their removal.
- *A good paragraph, but is overly wordy and the objectives are hidden at the end!*

# Scientific Writing

## Methods

- Study area
- Study design
- Sampling
- Data analysis

# Scientific Writing

## Methods

- Describe the **study area** in the first part of the Methods section.
- Clearly describe all physical, chemical, and biological attributes of the study area.
  - Describe the study area fully enough that readers can place the study in proper context.
  - Readers likely do not know your study area well enough to know how your findings may apply to their own resources.

# Scientific Writing

## Methods

- Describe the **study design** in the second part of the Methods section.
- Clearly describe the sampling units and their distribution in space and time.
  - Is the study design described clearly enough that readers understand what was measured, how measurements were distributed in space and time, and thus how spatial and temporal variation in measurements was estimated?

# Scientific Writing

## Methods

- Describe the **sampling methods** in a logical, usually chronological, order.
- For a field study (for example):
  - How were the fish caught in the field (i.e. fully describe sampling gears)?
  - Which attributes were measured or sampled (e.g. length, weight, gender, and tissues)?
  - How were samples treated in the laboratory (e.g. age estimation, or tissue analysis)?

# Scientific Writing

## Methods

- Describe the **data analysis** unambiguously and completely.
- Ensure that each statistical test disclosed in the Results is described in the Methods!
  - What statistical test or procedure was applied to each question (check against objectives)?
  - What are the dependent and independent variables for each analytical model?
  - Avoid “fast and loose” descriptions!

# Scientific Writing

## Methods

- After writing the Methods section, apply the “acid test”:
  - Are the methods described fully enough that someone could reproduce your study?
  - If so, then the Methods are likely described fully enough.
  - If not, go back and revise until the “acid test” is passed!
- *Now, let's review the Methods section in Meyer et al. (2006)!*

# Scientific Writing

## Methods

- Study area – Paragraph 1, but only physical and biological features (no chemical features)
- Study design – Not explicitly described, so must be inferred from what was done (see next)
- Sampling – Paragraphs 2–4, with great detail about what went wrong
- Data analysis – Paragraphs 5–7 (abundance), Paragraphs 8–12 (demographic parameters)

# Scientific Writing

## Methods

- Voice: Used “We” 20 times and “WAG personnel or crews” 5 times to describe what was done.
- Jargon: Used “aged” twice when describing the way in which age was estimated:
  - “We aged a subsample ...” [“Age was estimated for a subsample...”]
  - “...for all aged brook trout...” [entire phrase could be deleted without loss of information]

# Scientific Writing

## Methods

- In 1998, WAG personnel performed removals in the lower 4.5 km of stream only but discovered that brook trout resided farther upstream than previously suspected.
- In 1998, brook trout were removed from the lower 4.5 km of stream before discovering that brook trout resided farther upstream.

# Scientific Writing

## Methods

- Because electrofishing is size selective (Reynolds 1996) and we wished to monitor yearly recruitment success, we estimated abundance separately for age-0 fish (<80 mm TL) and age-1 and older fish ( $\geq$ 80 mm TL).
- To monitor recruitment, abundance was estimated separately for age-0 fish (<80 mm TL) and age-1 and older fish ( $\geq$ 80 mm TL).

# Scientific Writing

## Results

- Organize
- Describe
- Fully disclose

# Scientific Writing

## Results

- **Organize** the results around the findings, which should relate to study objectives.
  - Begin by writing one paragraph for each figure or table.
  - Compose each paragraph in topic-sentence style while viewing a figure or table.
  - Tell readers what you see in the figure or table (emergent patterns, not details).
  - Never “discuss” a finding in the Results section!

# Scientific Writing

## Results

- **Describe** the findings in biological, not statistical, terms.
  - Statistical tools are means to an end, but are not otherwise important.
  - When describing a result, focus your description on why the test was used.
  - Use the word “significantly” whenever a test statistic is larger than expected by chance alone (defined by  $\alpha$  in Methods).
  - *“Live and die” by your statistical results!*

# Scientific Writing

## Results

- **Fully disclose** each statistical result at the end of a sentence that explains a biological meaning of the statistical result.
  - Include: (value of the test statistic; degrees of freedom; exact probability).
  - Fully inform, so readers can judge significance and power for themselves!
    - Most readers use their own criteria when they judge statistical significance!
    - Readers deserve to know the power of a test.

# Scientific Writing

## Results

- The results section should be really easy to write, but is troublesome for many authors.
  - Many authors can't seem to describe a figure or table (at least, not what they see).
  - Many authors can't seem to describe statistical results in biological terms.
  - Many authors think that P-values ( $P \leq$  or  $> 0.05$ ) are ample for judging statistical test results.
- *Now, let's review the Results section in Meyer et al. (2006)!*

# Scientific Writing

## Results

- Results paralleled the order of study objectives and methods.
- Figures and tables were each described in a separate topic-sentence paragraph.
- Descriptions of figures focused on patterns of change, rather than details of estimates.
- *Comparisons of size structure and fecundity were disclosed as naked P-values, and comparisons of weight-length were not shown.*

# Scientific Writing

## Results

### **Problem = Non-Parallel Order:**

- In 1998, 1,401 brook trout were removed from Pike's Fork; 1,241 brook trout were removed in 1999, and 890 were removed in 2000.
- Brook trout removed from Pike's Fork included 1,401 in 1998, 1,241 in 1999, and 890 in 2000.

# Scientific Writing

## Results

### **Problem = English 101 & Yoda Speak:**

- While brook trout were being removed, there was no consistent increase in abundance of redband trout (Figure 1).
- Abundance of redband trout did not increase consistently while brook trout were being removed (Figure 1).

# Scientific Writing

## Discussion

- Organize
- Integrate
- Limit
- Conclude

# Scientific Writing

## Discussion

- **Organize** the discussion around each of the major findings.
  - Devote one paragraph to each finding (in the same order that they appeared in the Results).
  - Begin each paragraph with a general statement of how your finding compares to other studies.
  - Continue each paragraph with sentences that compare the details of related studies.

# Scientific Writing

## Discussion

- **Integrate** each of your findings with other related studies.
  - Never repeat statements that already appeared in the Results sections (redundant).
  - Rather, compare or contrast your findings to those of related studies (integrate).
  - Support each sentence with one or more citations to other relevant studies (cite).

# Scientific Writing

## Discussion

- **Limit** the discussion to the scope of your study and your findings.
  - Admit to the limitations of your study, but do not “discuss” topics not investigated.
  - Never “discuss” your findings without citing other relevant literature to support your statements.

# Scientific Writing

## Discussion

- **Conclude** with a paragraph (or section) that tells readers what your findings mean.
  - If a single paragraph, append to the end of the Discussion section.
  - If more than one paragraph, set off with a sub-heading (e.g. Management Implications).
  - Copy the topic sentence (primary conclusion) as the last sentence of the Abstract.
- *Now, let's review the Discussion section in Meyer et al. (2006)!*

# Scientific Writing

## Discussion

- Organized in parallel topic order as Objectives, Methods, and Results... (Paragraphs 1–3)
- *Objectives were poorly integrated with other studies...(3 citations in Paragraphs 1–3)*
- *Most sentences merely repeated the same findings as were described in the Results!*
- *Too much of the discussion (6 of 10 paragraphs) explained shortcomings of the study!*
- Concluding paragraph succinctly synthesized the entire study.

# Scientific Writing

## Discussion

- Used “we” 21 times...none of which reported others’ conclusion...
- Led with authors names 6 times...
  - McFadden (1977) pointed out...
  - Previous studies (Riley and Fausch 1992; Peterson et al. 2004b; Rosenberger and Dunham 2005) have demonstrated...
  - Peterson et al. (2004b) found...
  - Adams et al. (2000) found...
  - Meyer et al. (2006) estimated...

# Scientific Writing

## Discussion

- A more likely explanation was given by McFadden (1977), who argued that the complexity of interactions between several compensatory response mechanisms may lead to the operation of only one or a few mechanisms under certain environmental conditions, preempting the operation of other mechanisms.
- Complex interactions among compensatory responses may lead to one or a few preempting the others (McFadden 1977).

# Scientific Writing

## References

- Ensure that all text citations match an item in the list of references.
- Carefully format references to conform to the target journal's style guidelines.
- Review a recent issue of the target journal to see how references are formatted.
- Some journals now use a computer algorithm to reformat references.

# Scientific Writing

## Tables and Figures

- Elements of table and figure captions:
  - **What** is shown in the table or figure?
  - **Where** were the results obtained?
  - **When** were the results obtained?
- Tables are often keyed (not scanned) when type set, so you must review each digit of each number in tables of galley proofs!
- Figures are scanned as images when type set, so you don't need to review accuracy.

# Scientific Writing

## Tables

- Tables should show results that are best shown as absolute values.
- Tables that do not convey a clear simple image may require study (simplify these).
- Carefully format tables to mimic those in a recent issue of the target journal.

# Scientific Writing

## Tables

- Elements of table style:
  - Report only the appropriate number of digits.
  - Organize elements into more rows than columns.
  - Use only horizontal lines to set off table parts:
    - Pair of horizontal lines set off column headings.
    - May use short horizontal lines to set off sub-columns.
    - Bottom line encloses the bottom of the table.
    - Never use vertical lines in a table!
- *Let's review tables in Meyer et al. (2006)...*

# Scientific Writing Tables

TABLE 1.—Estimated total abundance (with lower and upper 95% confidence limits [CLs]), capture probabilities (CPs), and removal efficiencies (REs) for brook trout captured in Pike’s Fork, Idaho, during August backpack electrofishing surveys, 1998–2003; blank cells indicate parameters or years where results could not be estimated.

Year	Lower 4.8 km of stream					Entire 7.8-km reach				
	Total abundance			Mean CP	Estimated RE	Total abundance			Mean CP	Estimated RE
	Lower 95% CL	Estimate	Upper 95% CL			Lower 95% CL	Estimate	Upper 95% CL		
<b>Age 1 and older</b>										
1998	688	699	725	0.83	0.98					
1999	671	699	773	0.82	0.96	1,127	1,180	1,312	0.81	0.96
2000	165	207	394		0.42	510	629	973		0.81
2003	48	100	152	0.82		376	655	935	0.81	
<b>Age 0</b>										
1998	713	796	890	0.69	0.90					
1999	56	110	192		0.29	114	224	390		0.51
2000	156	198	369		0.42	380	498	798		0.76
2003	39	517	1,157	0.62		1,014	1,832	2,650	0.68	

# Scientific Writing Tables

TABLE 2.—Estimated total brook trout abundance by stream reach and age-group in Pike’s Fork, Idaho, 1998–2003. At age 2, fish apparently became fully recruited to the electrofishing gear (see text) and estimates thus became more reliable. Removal was not conducted in 2001 or 2002. Blank cells indicate years when results could not be estimated.

Age	Lower 4.5 km				Upper 3.3 km				Entire 7.8 km			
	1998	1999	2000	2003	1998	1999	2000	2003	1998	1999	2000	2003
0	796	110	198	517		114	300	1,315		224	498	1,832
1	198	455	106	83		227	126	460		683	228	543
2	457	191	81	17		200	225	95		389	308	112
3	44	46	20	0		49	62	0		95	82	0
4	0	7	0	0		5	9	0		13	10	0
5	0	0	0	0		0	0	0		0	1	0
Total	1,495	809	405	617		595	722	1,870		1,404	1,127	2,487

# Scientific Writing

## Figures

- Figures should show results that are best shown as patterns of values.
- Figures should convey a clear simple image, so should not require much study.
- Carefully format figures to mimic those in a recent issue of the target journal.

# Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods

WILLIAM S. CLEVELAND and ROBERT McGILL\*

The subject of graphical methods for data analysis and for data presentation needs a scientific foundation. In this article we take a few steps in the direction of establishing such a foundation. Our approach is based on *graphical perception*—the visual decoding of information encoded on graphs—and it includes both theory and experimentation to test the theory. The theory deals with a small but important piece of the whole process of graphical perception. The first part is an identification of a set of *elementary perceptual tasks* that are carried out when people extract quantitative information from graphs. The second part is an ordering of the tasks on the basis of how accurately people perform them. Elements of the theory are tested by experimentation in which subjects record their judgments of the quantitative information on graphs. The experiments validate these elements but also suggest that the set of elementary tasks should be expanded. The theory provides a guideline for graph construction: Graphs should employ elementary tasks as high in the ordering as possible. This principle is applied to a variety of graphs, including bar charts, divided bar charts, pie charts, and statistical maps with shading. The conclusion is that radical surgery on these popular graphs is needed, and as replacements we offer alternative graphical forms—*dot charts*, *dot charts with grouping*, and *framed-rectangle charts*.

**KEY WORDS:** Computer graphics; Psychophysics.

## 1. INTRODUCTION

Nearly 200 years ago William Playfair (1786) began the serious use of graphs for looking at data. More than 50 years ago a battle raged on the pages of the *Journal of the American Statistical Association* about the relative merits of bar charts and pie charts (Eells 1926; Croxton 1927; Croxton and Stryker 1927; von Huhn 1927). Today graphs are a vital part of statistical data analysis and a vital part of communication in science and technology, business, education, and the mass media.

Still, graph design for data analysis and presentation is

largely unscientific. This is why Cox (1978) argued, "There is a major need for a theory of graphical methods" (p. 5), and why Kruskal (1975) stated "in choosing, constructing, and comparing graphical methods we have little to go on but intuition, rule of thumb, and a kind of master-to-apprentice passing along of information. . . . there is neither theory nor systematic body of experiment as a guide" (p. 28–29).

There is, of course, much good common sense about how to make a graph. There are many treatises on graph construction (e.g., Schmid and Schmid 1979), bad practice has been uncovered (e.g., Tufte 1983), graphic designers certainly have shown us how to make a graph appealing to the eye (e.g., Marcus et al. 1980), statisticians have thought intensely about graphical methods for data analysis (e.g., Tukey 1977; Chambers et al. 1983), and cartographers have devoted great energy to the construction of statistical maps (Bertin 1973; Robinson, Sale, and Morrison 1978). The ANSI manual on time series charts (American National Standards Institute 1979) provides guidelines for making graphs, but the manual admits, "This standard . . . sets forth the best current usage, and offers standards 'by general agreement' rather than 'by scientific test'" (p. iii).

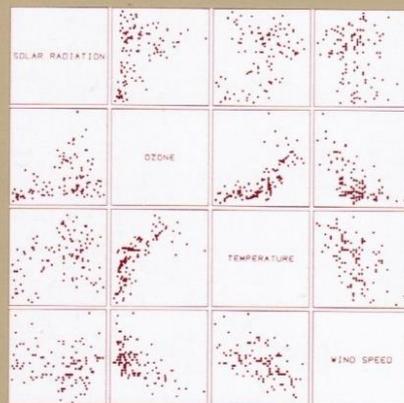
In this article we approach the science of graphs through human graphical perception. Our approach includes both theory and experimentation to test it.

The first part of the theory is a list of elementary perceptual tasks that people perform in extracting quantitative information from graphs. In the second part we hypothesize an ordering of the elementary tasks based on how accurately people perform them. We do not argue that this accuracy of quantitative extraction is the only aspect of a graph for which one might want to develop a theory, but it is an important one.

The theory is testable; we use it to predict the relative performance of competing graphs, and then we run experiments to check the actual performance. The experiments are of two types: In one, once the graphs are drawn, the evidence appears so strong that it is taken *prima facie* to have established the case. When a strong effect is perceived by the authors' eyes and brains, it is likely that it will appear to most other people as well. In

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# THE ELEMENTS OF GRAPHING DATA



\* William S. Cleveland and Robert McGill are statisticians at AT&T Bell Laboratories, Murray Hill, NJ 07974. The authors are indebted to John Chambers, Ram Ganadesikan, David Krantz, William Kruskal, Colin Mallows, Frederick Mosteller, Henry Pollak, Paul Tukey, and the JASA reviewers for important comments on an earlier version of this article.

# Scientific Writing

## Figures

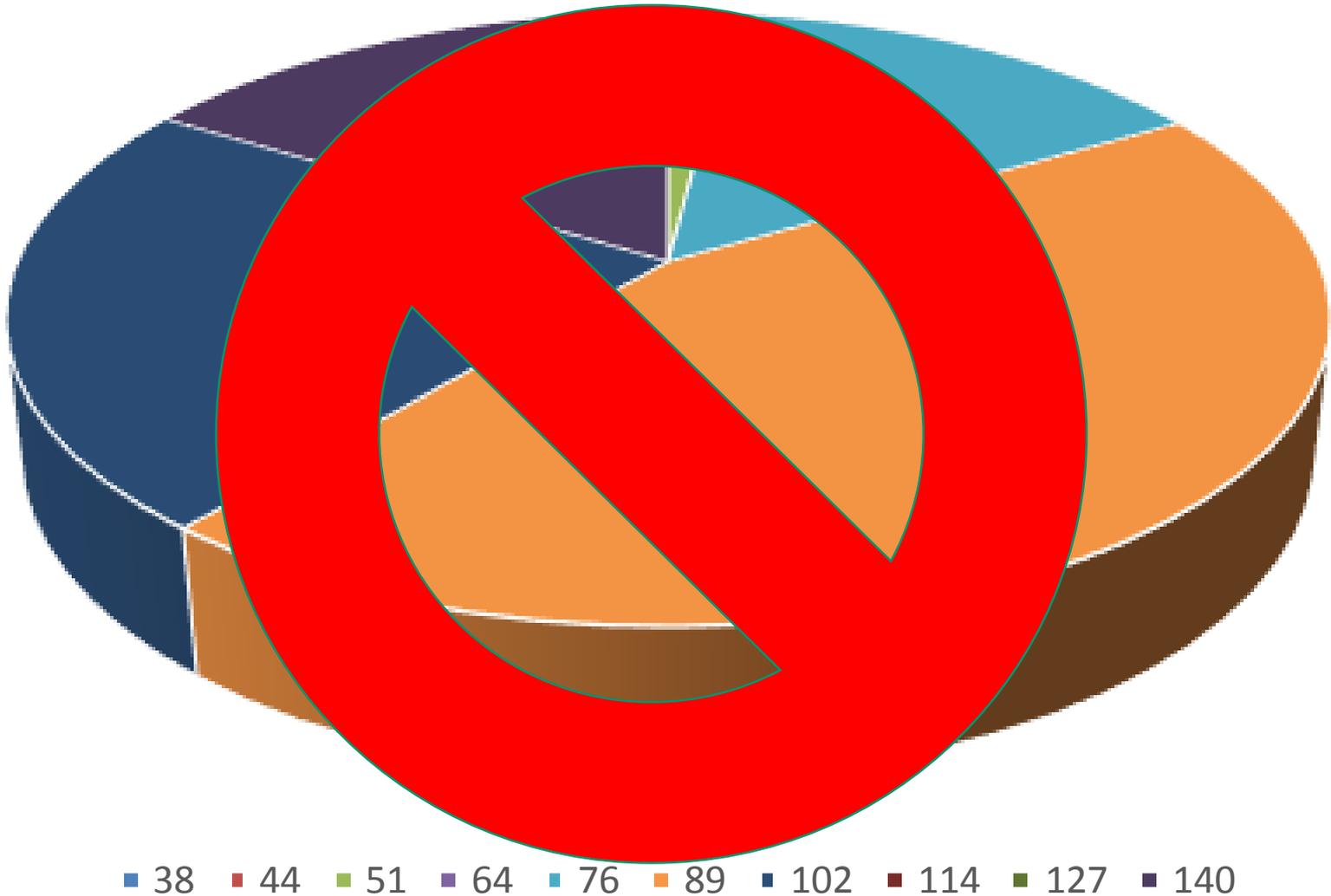
- Elements of figure style:
  - Avoid chart junk (3-D bars, embellishments).
  - Retain only data within axes (tick marks out).
  - Use large font for all text (arm's length test).
  - Include only x-axis and y-axis (no box).
  - Use only black-and-white (no gray).
  - Axes should be equal in size (height = width).

# Scientific Writing

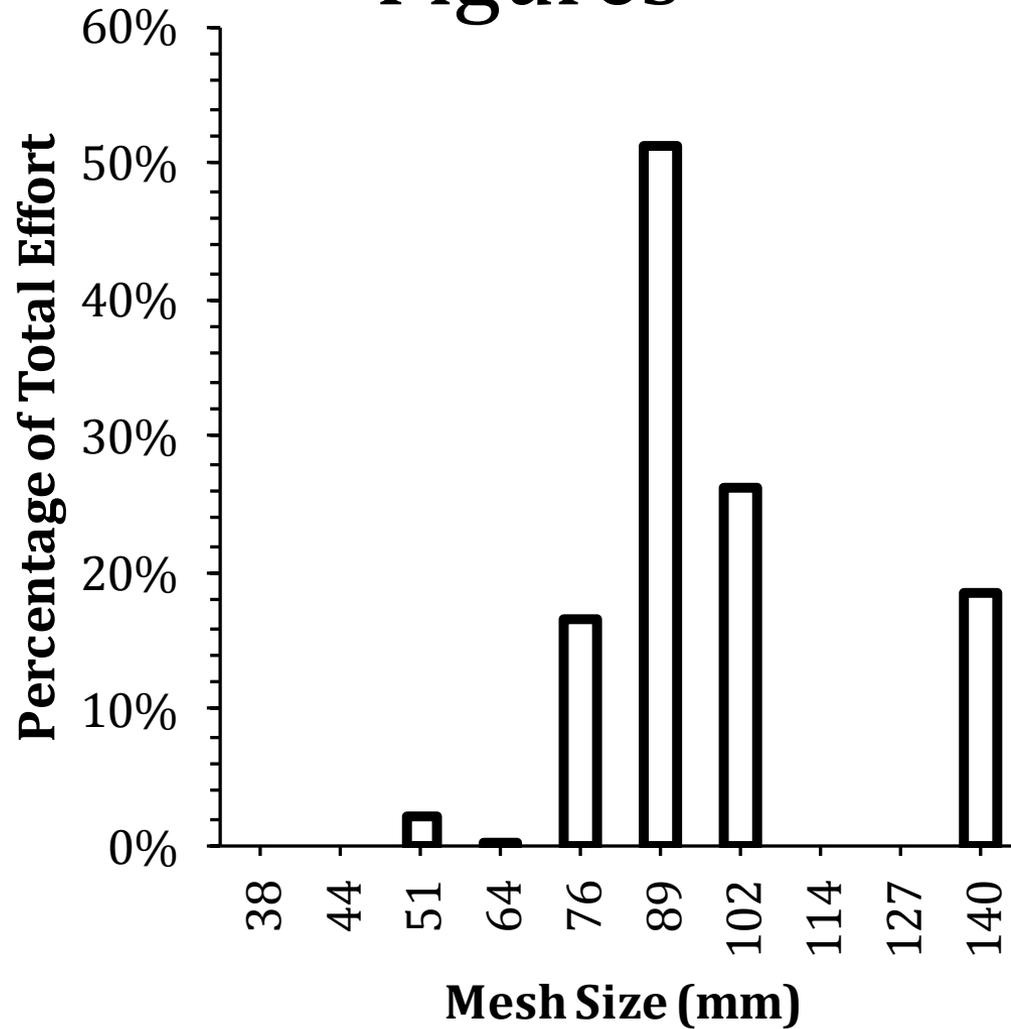
## Figures

- Never use embellishments just because you can (availability  $\neq$  appropriateness)!
- Never assume default settings of graphs in software packages are appropriate!
- Default settings for graphs from nearly all graphics packages are *all bad!*
- NEVER use pie charts for presentation of any data...ALWAYS use bar charts instead!

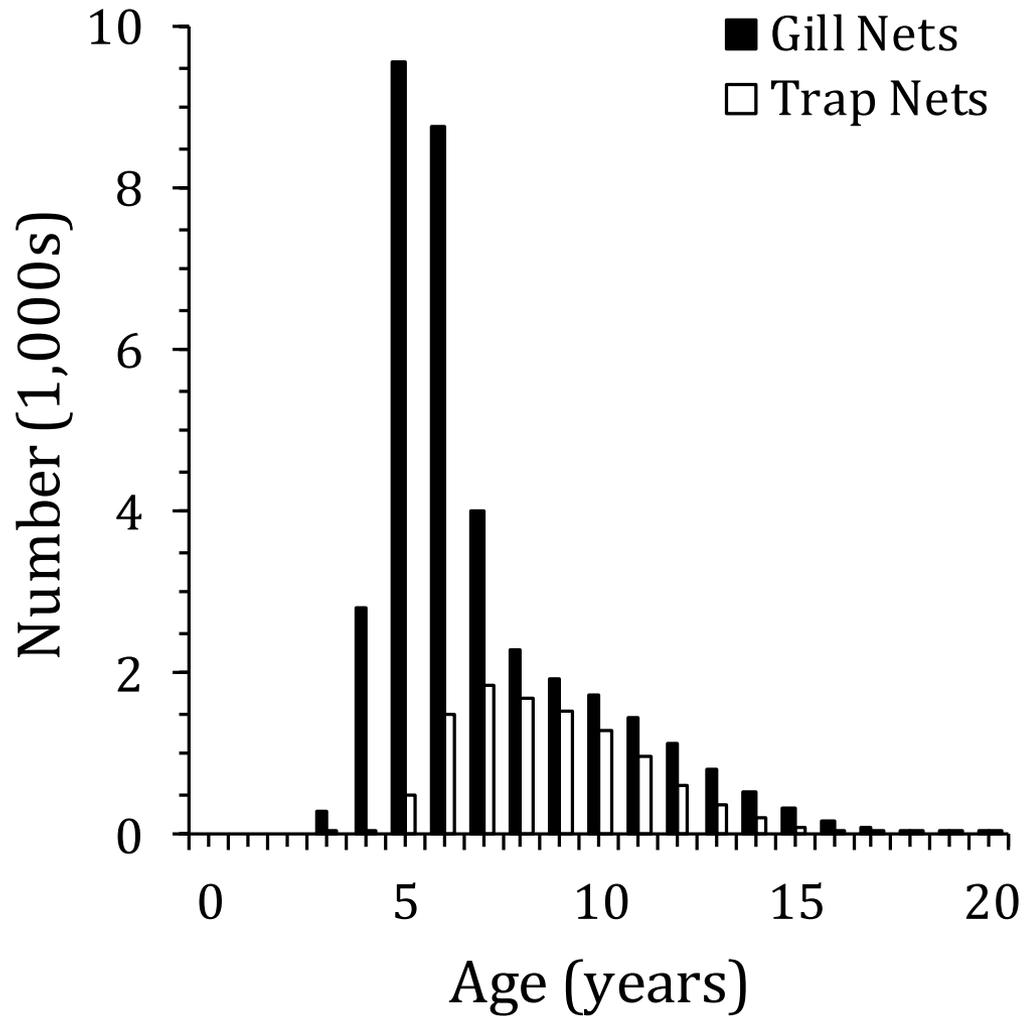
# Scientific Writing Figures



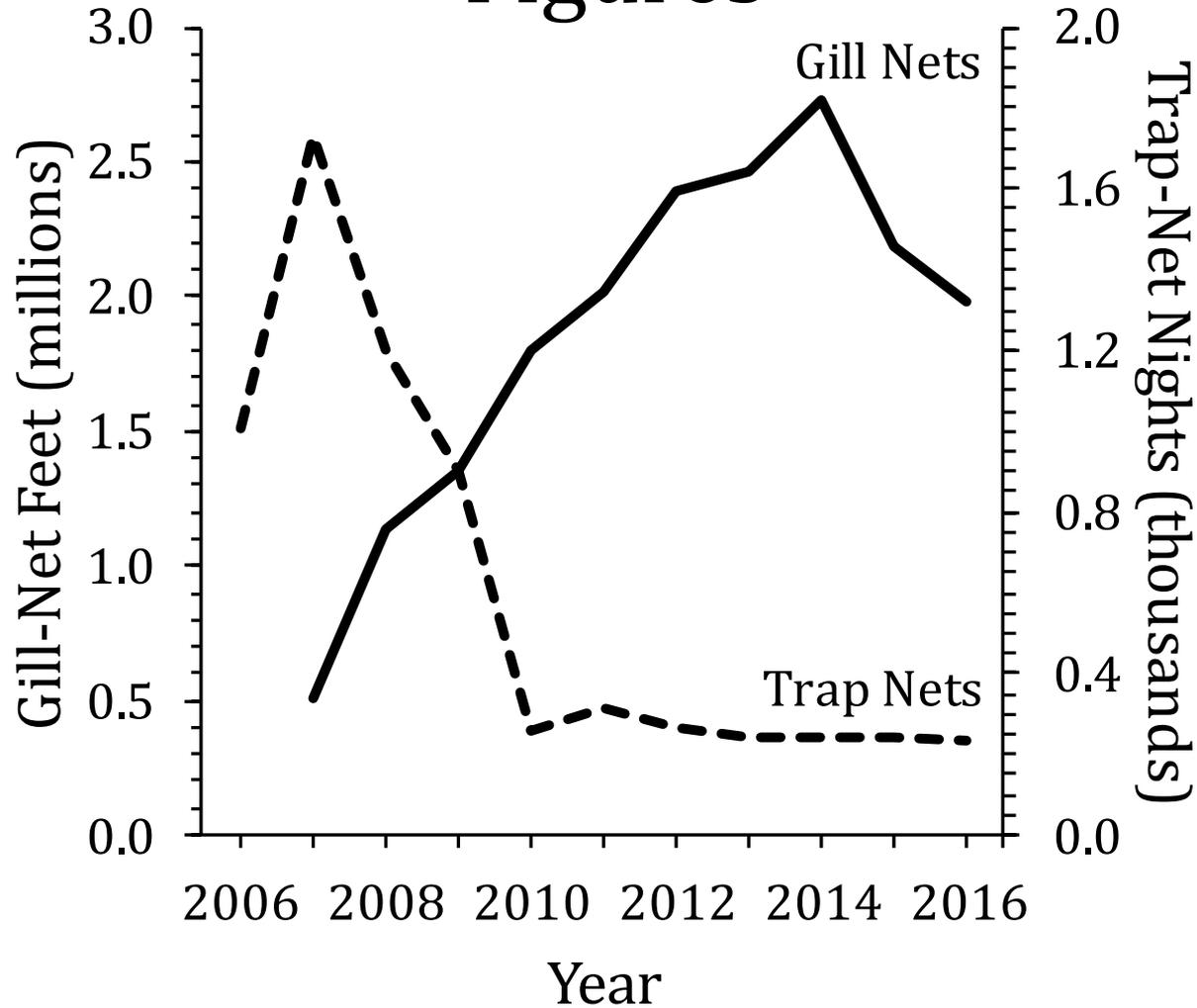
# Scientific Writing Figures



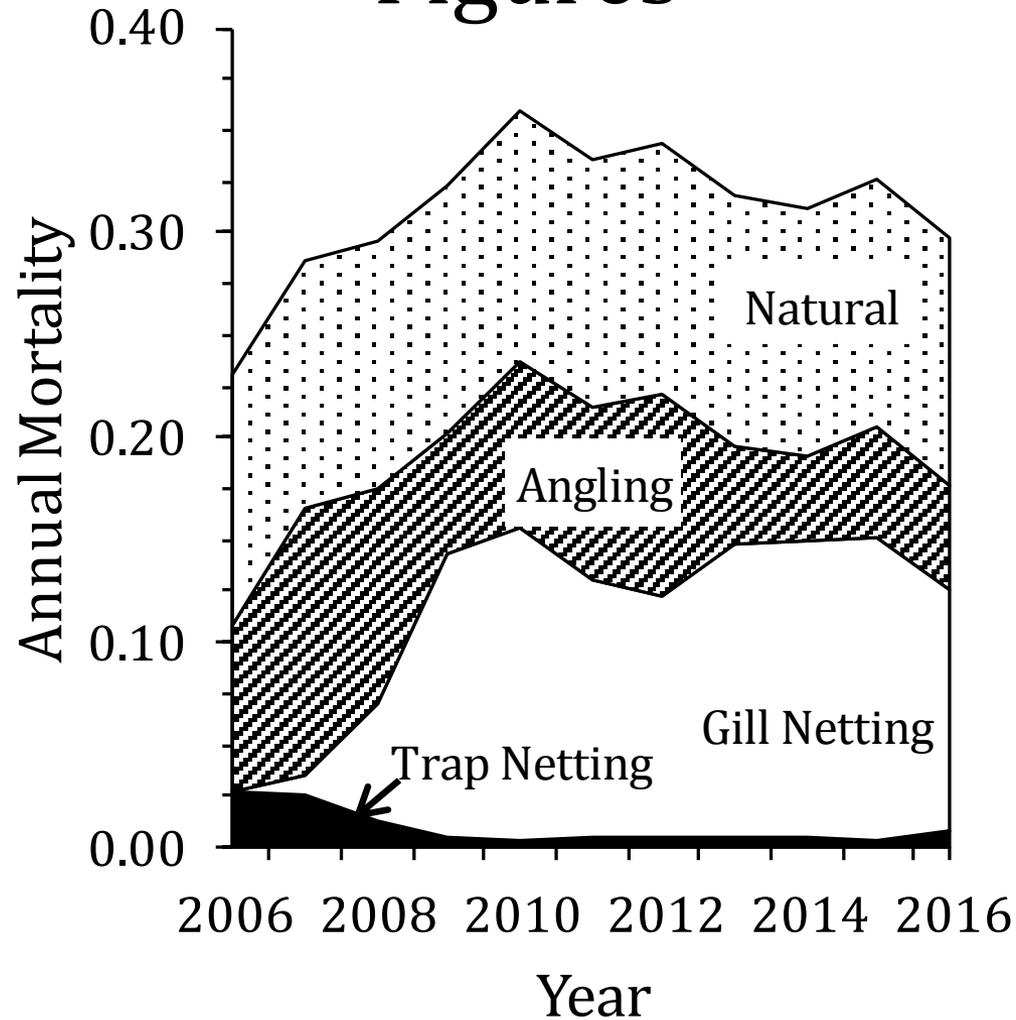
# Scientific Writing Figures



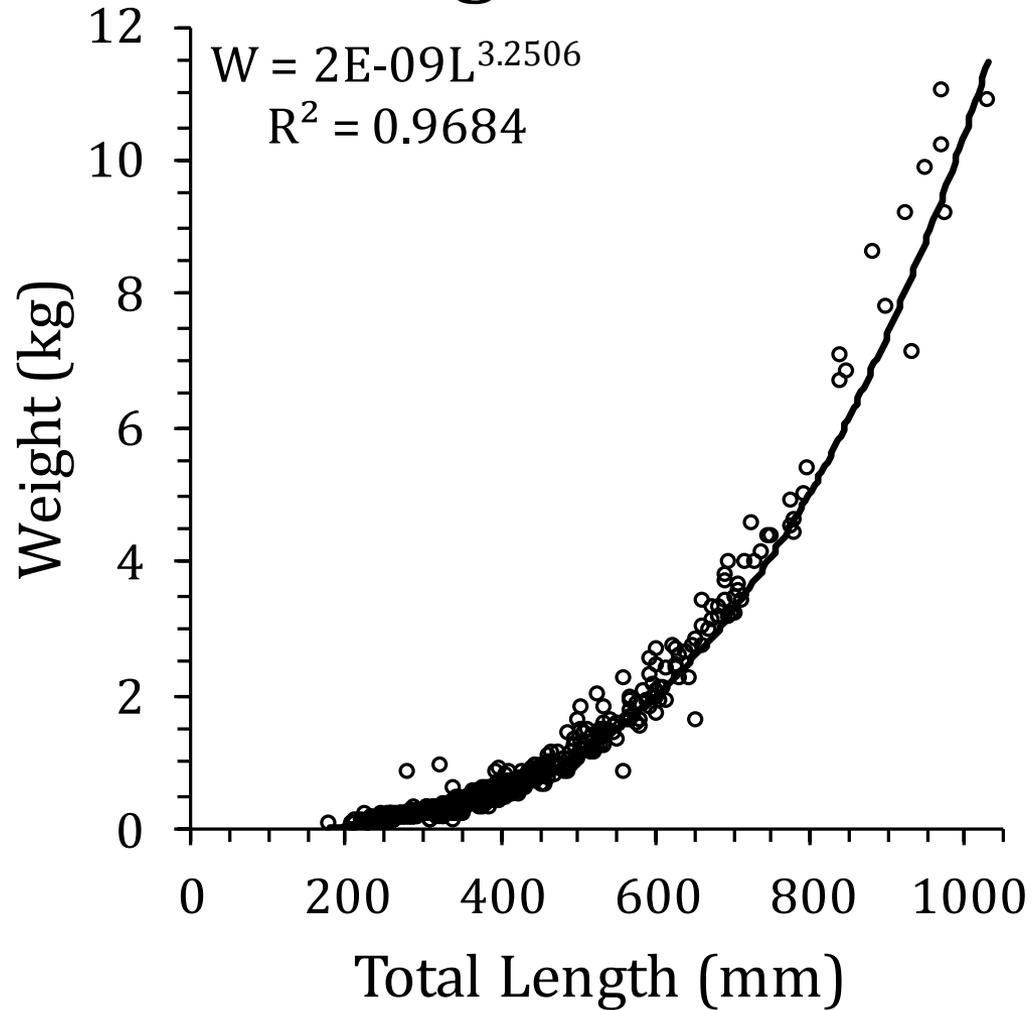
# Scientific Writing Figures



# Scientific Writing Figures

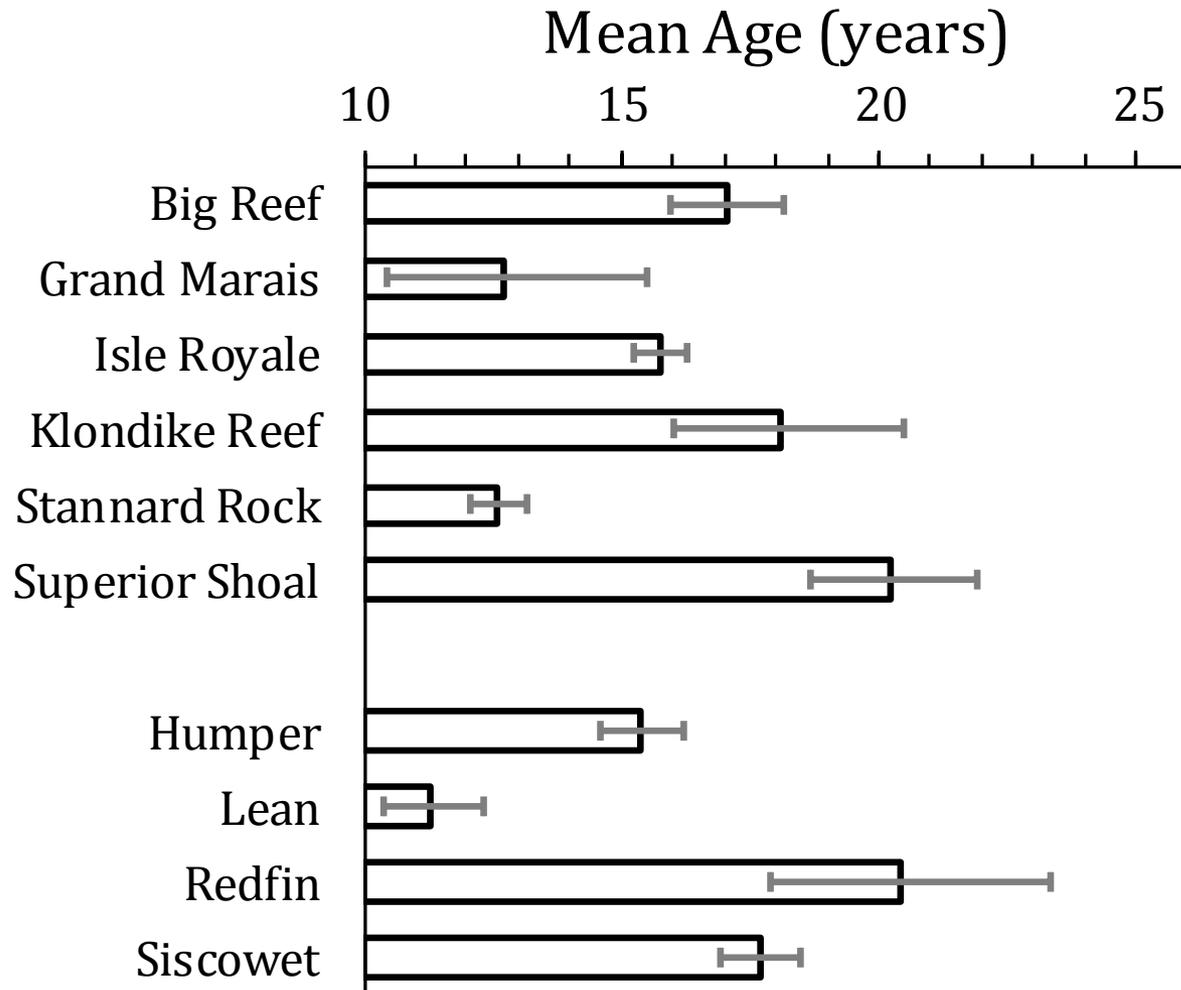


# Scientific Writing Figures



# Scientific Writing

## Figures



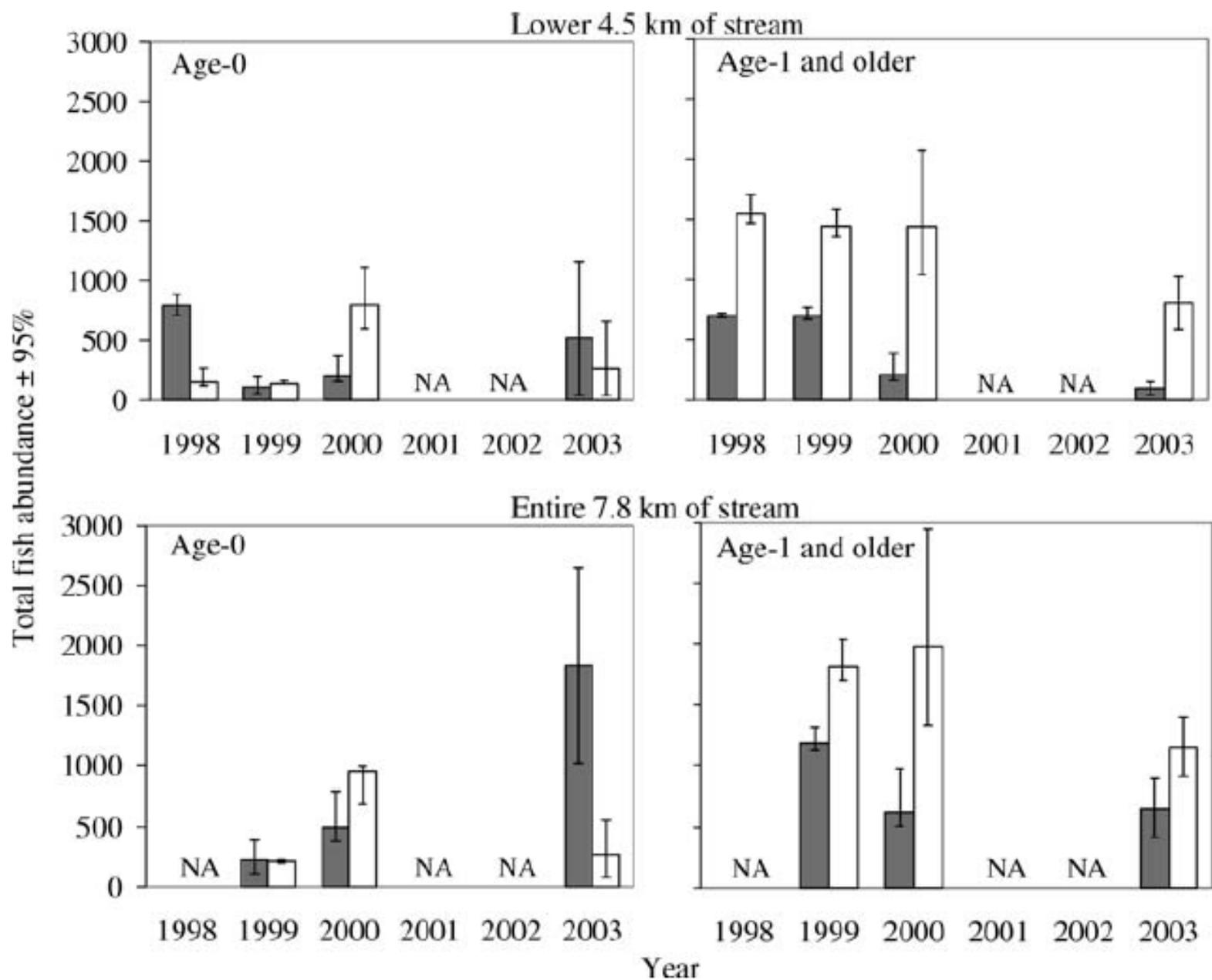


FIGURE 1.—Abundance ( $\pm 95\%$  CI) of nonnative brook trout (shaded) and native redband trout (unshaded) in Pike's Fork, Idaho, upstream of a man-made barrier during 1998–2003. Electrofishing removal of brook trout was conducted in all years except 2001 and 2002.

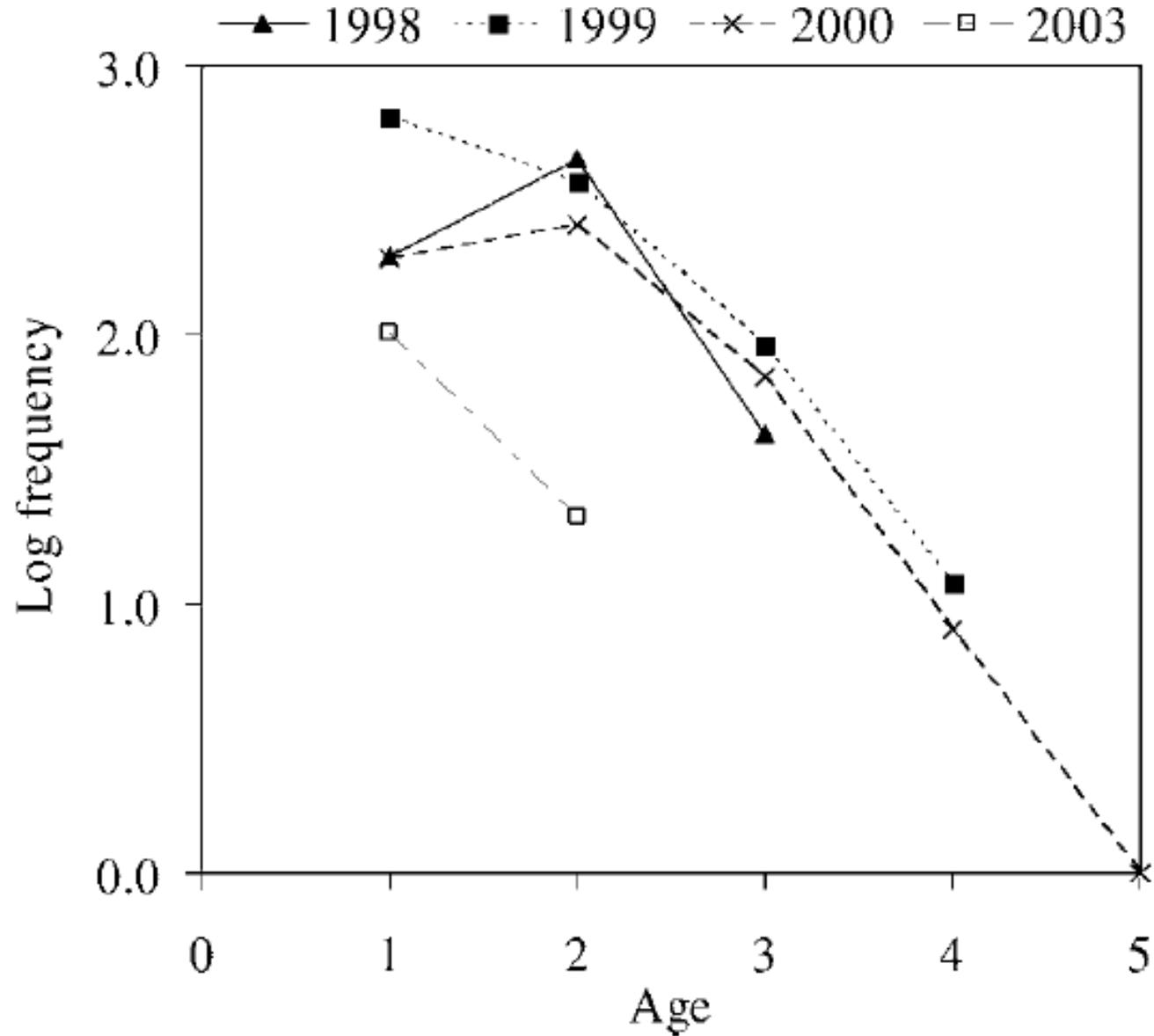


FIGURE 2.—Catch curves for nonnative brook trout removed by electrofishing in Pike’s Fork, Idaho, during 1998–2000 and 2003.

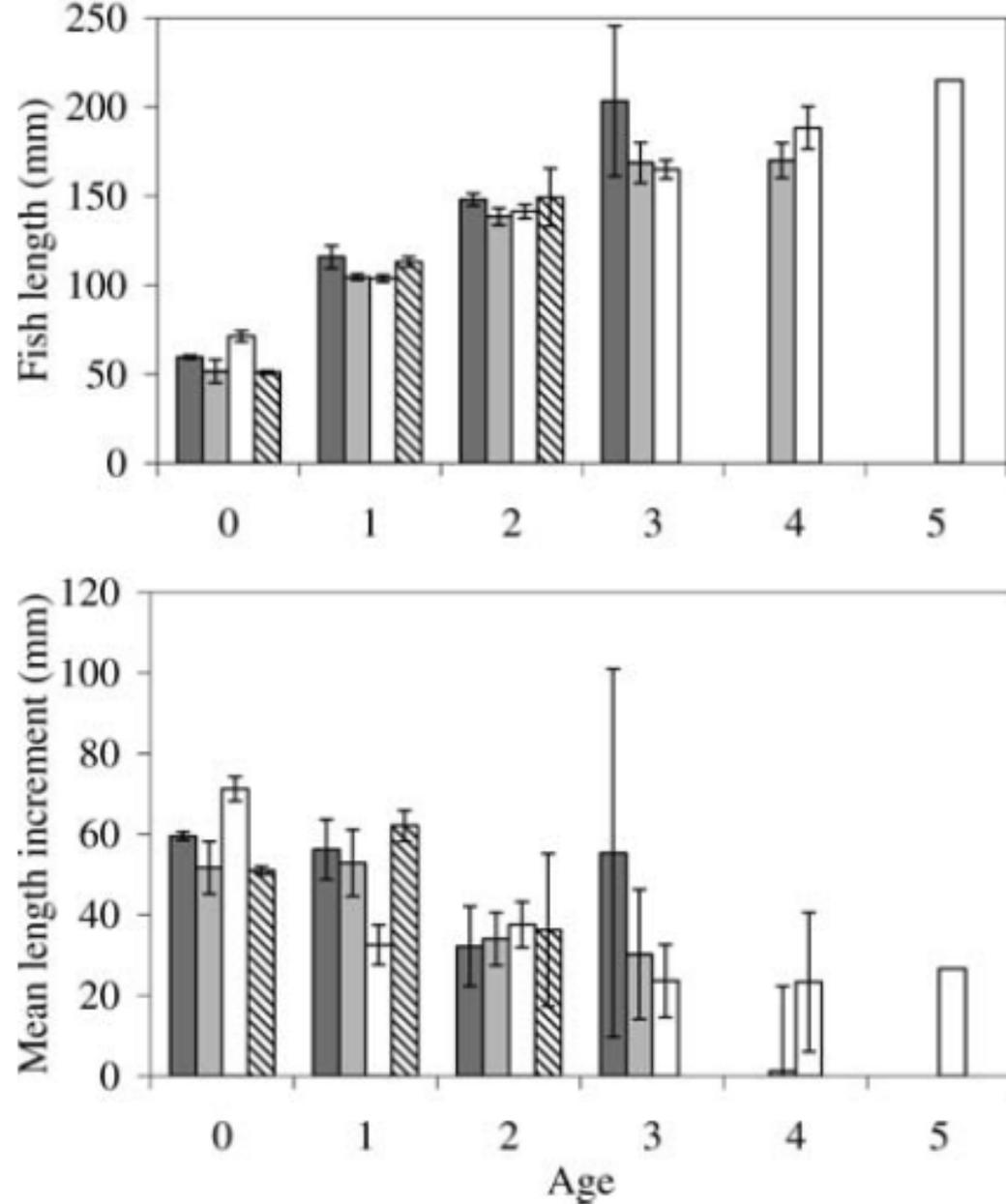


FIGURE 3.—Mean ( $\pm 95\%$  CI) length at age and length increment for nonnative brook trout removed by electrofishing in Pike's Fork, Idaho, during 1998–2000 and 2003.

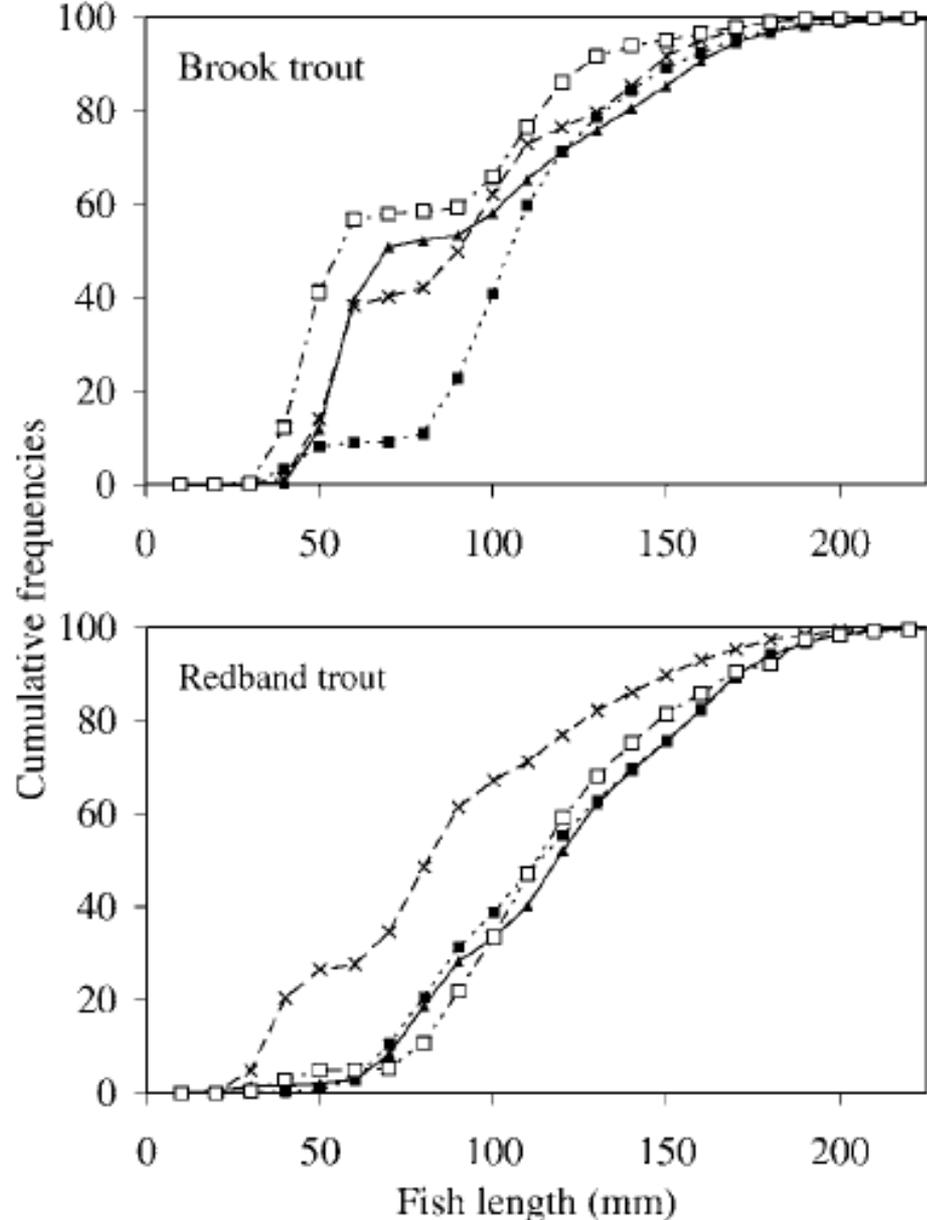


FIGURE 4.—Cumulative length frequencies of nonnative brook trout and native redband trout in Pike’s Fork, Idaho, during 1998–2003. Electrofishing removal of brook trout was conducted in all years except 2001 and 2002.

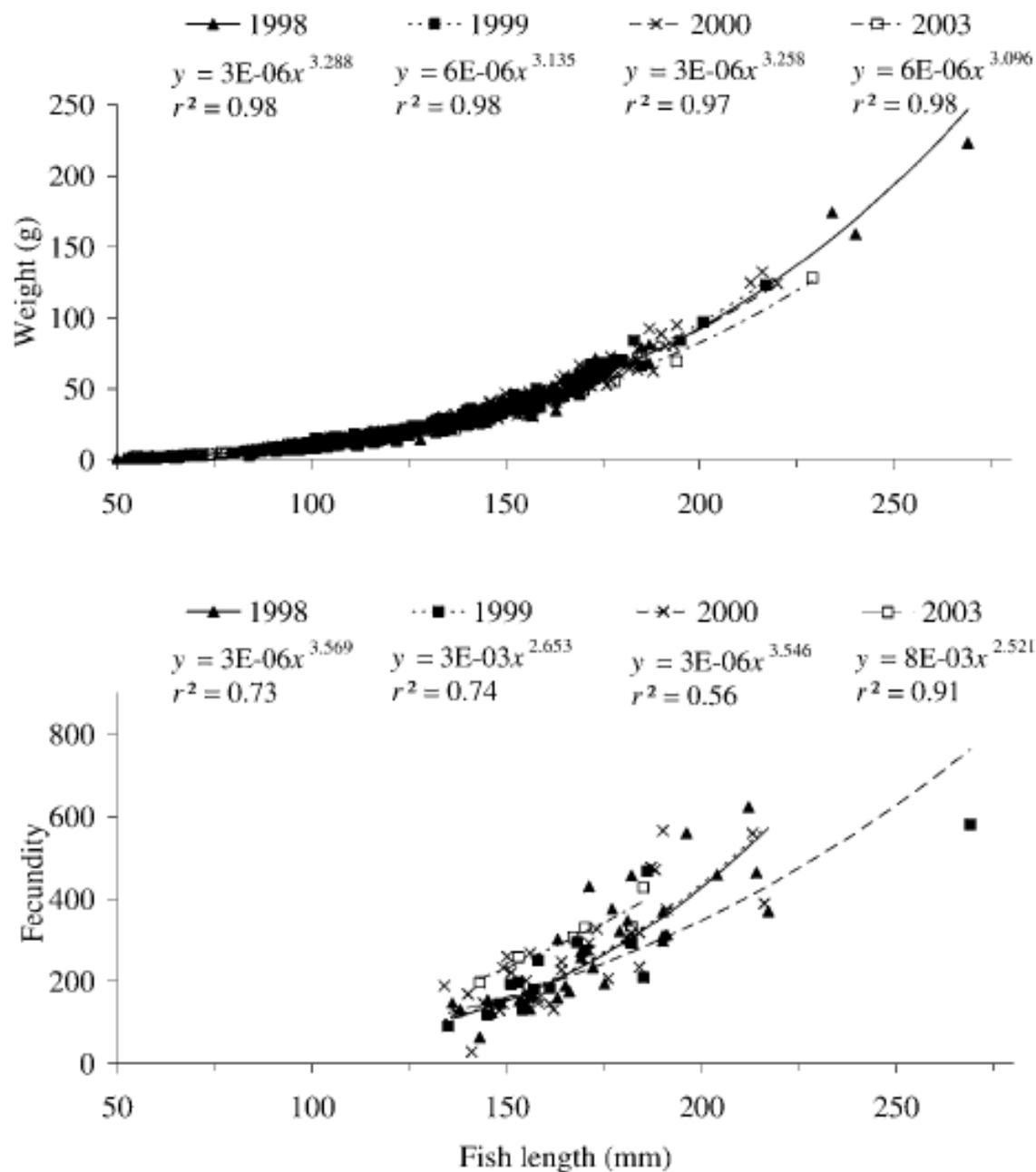


FIGURE 5.—Length–weight and length–fecundity relationships for nonnative brook trout removed by electrofishing in Pike’s Fork, Idaho, during 1998–2000 and 2003. Length is total length (mm).

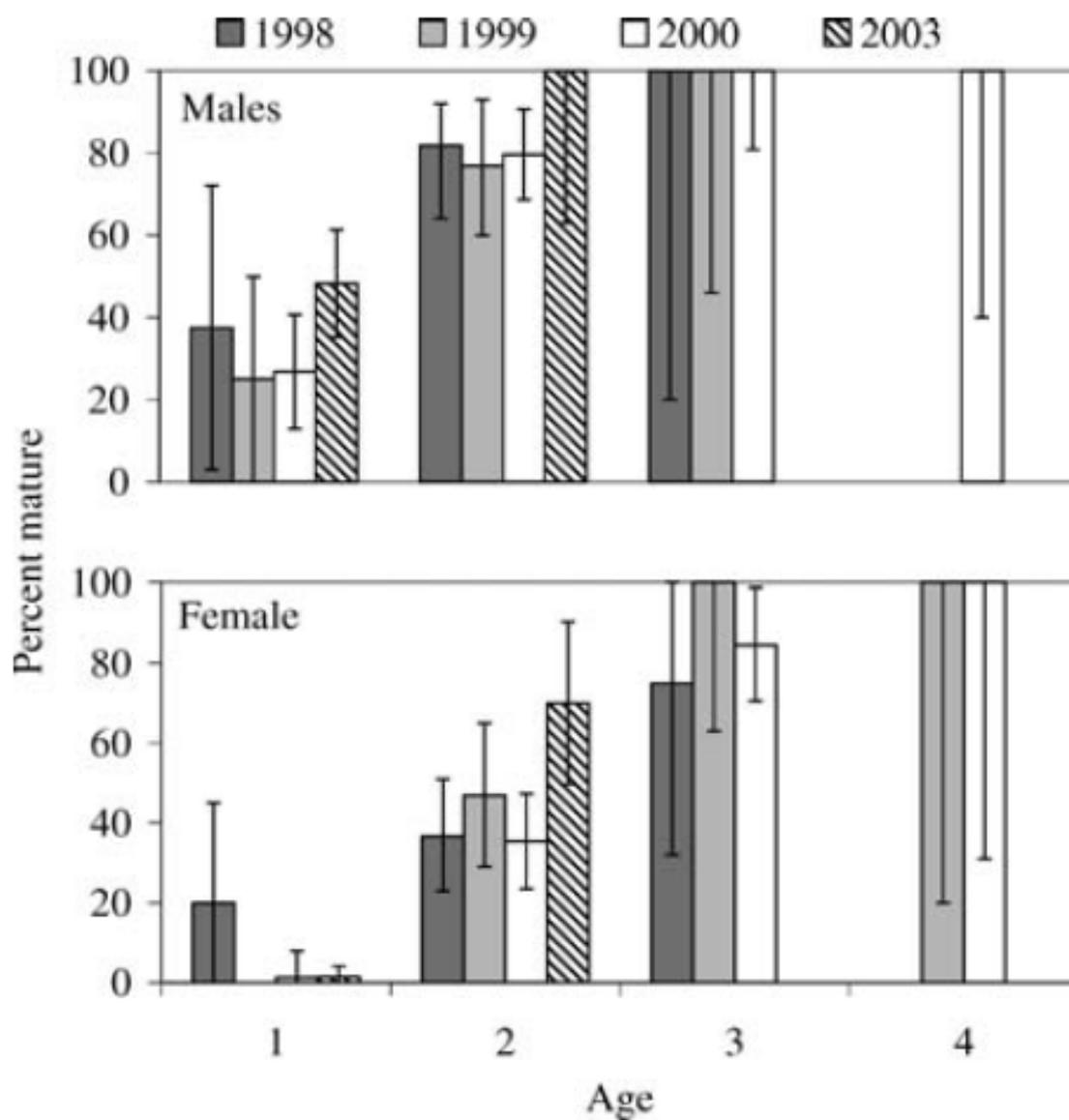


FIGURE 6.—Percentage ( $\pm 95\%$  CI) of nonnative brook trout males and females that were mature at each age in Pike's Fork, Idaho, during 1998–2003. Electrofishing removal of brook trout was conducted in all years except 2001 and 2002.

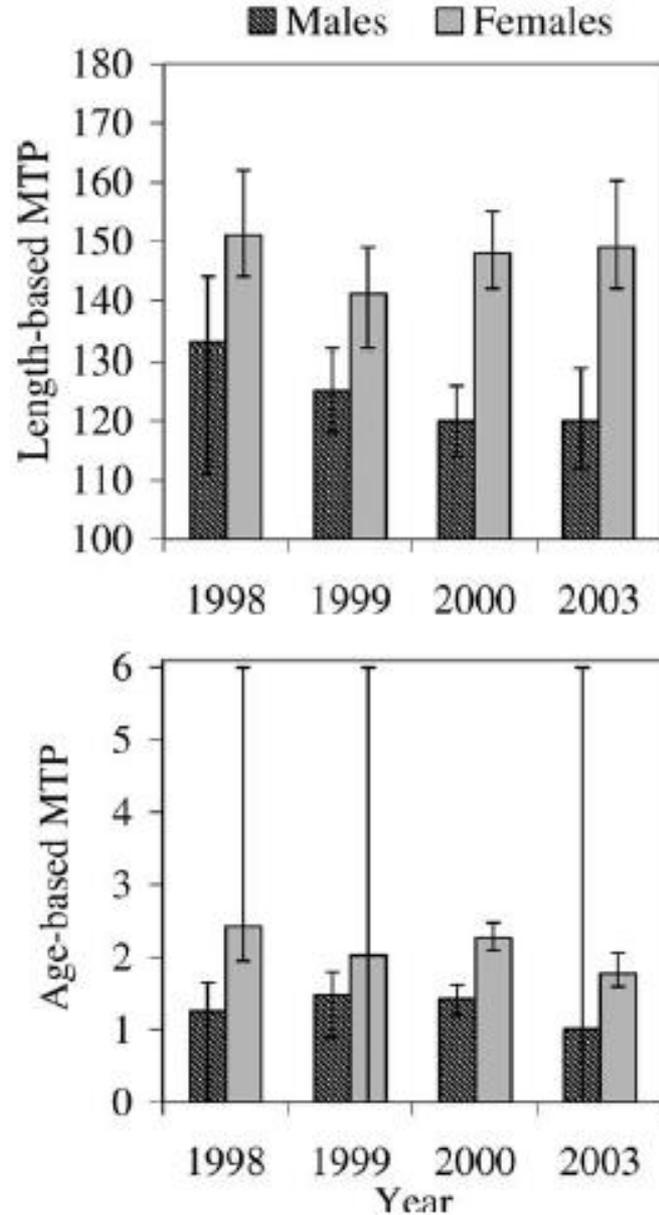


FIGURE 7.—Length-based (TL, mm) and age-based maturity transition points (MTPs; points where maturity probability = 0.50) ( $\pm$ 95% CI) calculated from logistic regression models for nonnative brook trout males and females in Pike's Fork, Idaho, during 1998–2003. Electrofishing removal of brook trout was conducted in all years except 2001 and 2002.

# Writing and Editing Workshop Format

- Part 2 – Scientific Editing  
*(Rely heavily on what you  
learned in the previous part of  
this workshop!)*

# Scientific Editing

## Preamble

- You have the right to refuse, but you have the responsibility to accept.
- You have the right to remain anonymous, but you are responsible for everything you say.
- You have the right to be honest, but you must also be respectful.
- You do NOT have the right to share the manuscript with others!

# Scientific Editing

## Principles

- Focus on content, not style!
  - Are objectives clear and well justified?
  - Are methods understandable and repeatable?
  - Are findings appropriate for objectives?
  - Are findings integrated with related literature?
- Let editors worry about format and style!
  - Editorial process is now highly mechanized.
  - Your ideas about format or style may not agree with those of the journal or editors.

# Scientific Editing

## Overall Assessment

- How much does the study contribute to fishery science?
- Is the information new or has it previously been published?
- Would the information be more appropriate for another publication outlet?
- Are elements of the study fatally flawed (the only unequivocal basis for rejection)?

# Scientific Editing

## Rules for Rejection

- Your judgment is only a recommendation to the editors about how they should proceed!
- When should you recommend rejection?
  - Any paper written by someone who scuffed you up during your career (revenge is sweet!).
  - Any paper that contains data you would like to use in your own research (your new data!).
  - Any paper that undermines your published view of the natural world (enforce your world view!).

# Writing and Editing Questions?

- *Thanks to Kevin, James, and Dan for being such good sports (guinea pigs)!*