



Fisheries Centre Research Reports

2001 Volume 9 Number 1

**An annotated bibliography of
scientific literature (1751-2000)
pertaining to Steller sea lions
(*Eumetopias jubatus*) in Alaska**

ISSN 1198-6727

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**An Annotated Bibliography of Scientific Literature
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Steller Sea Lions (*Eumetopias jubatus*) in Alaska**

by

Andrea M. J. Hunter and Andrew W. Trites

**Published by
© The Fisheries Centre,
University of British Columbia
2204 Main Mall, Vancouver, B.C.
Canada, V6T 1Z4**

2001

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Fisheries Centre Research Reports 9(1): 40 pages

ISSN 1198 6727

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Director's Foreword

Every so often someone performs a tedious chore so helpful to the rest of us that it falls into the category of 'really, really useful'. In this respect, a special place in fisheries heaven is reserved for those who compile bibliographies. In this Fisheries Centre report Andrea Hunter and Andrew Trites have, for the first time, brought together all of the literature on Steller sea lions, starting with Georg Wilhelm Steller's own description in 1751. Moreover, the bibliography is enhanced with a detailed analysis of the topics and issues covered in each of the papers. The authors will get a chorus of 'thank you' echoing down the years, and, doubtless, a suitable reward in heaven.

Steller, a meticulous German who would have loved to see this volume, was the naturalist on Vitus Bering's 1741 expedition from the Tsarina Anna's Russia to what is now Alaska. Bering was a Dane serving in the Russian navy. The expedition was a tough call; among the hardships we find hard to comprehend today were scurvy, losing the other half of the expedition in a storm, shipwreck, over-wintering on what became known as Bering Island in Kamchatka, and having to cut the wood to build their own ship. They also ate the sea-cows they discovered there, but, unfortunately, that did not prove a hardship and reports of the sea-cow's suitability as living larders led to their extinction only 30 years later. Bering himself died that winter, along with half of his crew. But, apart from all that, the tough Steller had a pretty successful voyage for a naturalist, and, as well as our sea lion, lent his name to a duck, a jay and that sea-cow. An unexpected reward that Georg got in heaven was a kind of silicate crystal (Stellerite), first found on the Komandorski Islands in 1909.

Every time I see the name, the testy old editorial pedant within pops up to ask why, unlike the extinct sea-cow, the sea lion's

name lost its possessive. OED gives the use of the possessive *Steller's* in Bull. Amer. Mus. Nat. Hist. XVI (1902), and reports it still in use in an edition of the 'Islander' published in Victoria, BC in 1975. A 1926 paper by Engle has it (jolly good show!), and so does the Alaska Fish and Game Department's web site (capital!). But Hunter and Trites bibliography clearly shows that modern usage has dropped the possessive. (Not to say the hyphen in sea-lion. Harrumph!)

The report is the latest in a series of research reports published by the UBC Fisheries Centre. A list is shown on our web site at <http://fisheries.ubc.ca>. The series aims to focus on broad multidisciplinary problems in fisheries management, to provide a synoptic overview of the foundations and themes of current research, to report on work-in-progress, and to identify the next steps and ways that research may be improved.

Edited reports of the workshops, research in progress or, occasionally, bibliographies like this, are published in *Fisheries Centre Research Reports* and are distributed to the Fisheries Centre's members, all project or workshop participants. Further copies are available on request for a modest cost-recovery charge. Please contact the Fisheries Centre by mail, fax (see back cover), or email to 'office@fisheries.ubc.ca'.

Tony J. Pitcher

*Professor of Fisheries
Director, UBC Fisheries Centre*

ABSTRACT

We compiled an annotated bibliography of Steller sea lion literature that identifies the areas of research that have been undertaken to date, and whether or not they address the leading hypotheses proposed to explain the population decline in Alaska. We identified 263 scientific papers with a primary research focus on Steller sea lions. Of these, 110 articles were peer-reviewed publications in scientific journals, and 153 were other forms of publication (e.g., technical reports, unpublished reports, dissertations, etc.). The total number of Steller sea lion articles published per decade has risen exponentially from 4 in the 1940s to 120 in the 1990s. The bulk of scientific studies have focused on population dynamics, population distribution, ecology, census data, nutrition and behavior. Subject areas that have received low research attention include

predation on Steller sea lions, captive studies, metabolism and parasitology. Only 56 of the 263 scientific articles contained information relative to testing one of the 12 hypothesized causes of the Steller sea lion decline. The most frequently addressed hypothesis concerned juvenile mortality (24 papers). This was followed by competition with fisheries, starvation and regime shifts. Only 1 of the 263 articles addressed the role that killer whale predation may be playing in the decline of Steller sea lions. To date, over 9,149 pages pertaining to Steller sea lions have been printed (1,145 pages of primary publications and 8,004 pages of other publications). The relative number of articles that address or provide significant information to assess hypothesized causes of the population decline are few (< 35% of the sea lion literature per decade).

ACKNOWLEDGEMENTS

We are particularly grateful to Sonja Kromann from the National Marine Mammal Laboratory Library in Seattle, Washington, who helped locate articles. We also wish to thank David Rosen, Pamela Rosenbaum and Arliss Winship

from the University of British Columbia. Help with formatting was provided by Tom Bell. We acknowledge financial assistance from the Pacific Seafood Processors Association, and from the North Pacific Marine Science Foundation through the North Pacific Universities Marine Mammal Research Consortium.

INTRODUCTION

The first to publish a scientific paper on Steller sea lions was George William Steller in 1751 (Steller 1751). His paper named and identified the Steller sea lion as a unique species and was later translated by Miller and Miller (1899). Over 100 years after Steller's (1751) publication, a paper was published that measured the length of the intestine of a Steller sea lion (Engle 1926). This, in turn, was followed by a paper published in 1945 that described the growth and behavior of young sea lions (Scheffer 1945).

Today, over 600 papers and articles can be found on Steller sea lions authored by Americans, Canadians, Russians and Japanese. Much of the published research on Steller sea lions has been prompted in the United States by the Marine Mammal Protection Act of 1972, and more recently by the listing of the Steller sea lion under the U.S. Endangered Species Act in 1990 (NMFS 1992).

Compiling the available scientific literature on Steller sea lions is useful for those wishing to understand why Steller sea lion populations have declined. Understanding what is already known, or where more information is required, is useful to those who would like to assist in the recovery of Steller sea lions. It was with this in mind that we set out to develop an annotated bibliography of Steller sea lion research that identifies the areas of research that have been undertaken to date. We also wanted to determine which scientific papers have information that bears on the leading hypotheses proposed to explain the decline of Steller sea lions. It is our hope that this information will be useful to scientists and non-scientists concerned with Steller sea lions as they seek to understand what is currently known and attempt to resolve why Steller sea lion populations have declined in parts of Alaska.

METHODS

There are three major sources for identifying scientific literature pertaining to Steller sea lions. One is a Pinniped Bibliography (Ronald *et al.* 1976). Another is electronic citation indexes, where published articles can be searched by species name or topic. A third source is the Steller sea lion bibliography

compiled by the National Marine Fisheries Service (Strick 1993) that contains over 400 entries.

We drew our compilation of the scientific literature primarily from the NMFS bibliography (Strick 1993) and supplemented it with additional citations from the other two sources. A large number of the cited articles in the NMFS bibliography are magazine articles or internal memorandums. We wished to restrict our analyses of the literature to scientific articles that focused primarily on Steller sea lions, and to those that might provide some insight into the Steller sea lions' ecosystem in Alaska.

The criteria we used to include articles in our annotated bibliography of Steller sea lion literature were:

1. Articles must be scientific. Newspaper and magazine articles were not included.
2. The Steller sea lion must be one of the primary focuses of the article and/or the article must provide a new perspective on Steller sea lion research. Articles that briefly mentioned Steller sea lions were omitted. Papers or book chapters that summarized existing Steller sea lion information and did not provide any new information were not included.
3. Articles were selected that reflected Steller sea lions present in the Alaska ecosystem. Thus, the majority of articles contained in our annotated bibliography pertained to research conducted in Alaska. However, relevant papers from outside of Alaska were included if they contributed knowledge or insight into the Steller sea lion population decline in Alaska.
4. Conference abstracts or non-peer-reviewed proceedings were not included because they were considered to be works-in-progress or incomplete studies that would eventually be published and replicated in the literature. However, workshop proceedings were included because they tended to provide new, original insight from groups of knowledgeable researchers.

Each article selected with the above criteria was categorized by (1) subject area and (2) hypotheses tested (i.e., whether they tested or provided significant new information to address the leading hypotheses proposed to explain the decline of Steller sea lions). Grouping scientific papers by subject area is a useful way to retrieve papers on a specific topic from the reference list. It also provides a simple means of determining what subject areas researchers have been focusing upon.

SUBJECT AREAS

The subject areas we chose to categorize the papers were modeled after those presented by Ronald *et al.* (1976), with slight modifications. The following is a list of the 46 keywords we chose with a brief description of the topics classified under each heading:

1. *Anatomy*
2. *Behavior*
3. *Bibliography:*
Any paper that is a summary or a review
4. *Biochemistry:*
Including pesticide residues, nutritional values of seal products, blood chemistry
5. *Captive Studies:*
Including zoos, aquariums, museums, care and handling
6. *Census data:*
Counts of Steller sea lions
7. *Circulatory System:*
Including lymphatic system, and structure of circulatory system (e.g., veins, heart), while excluding blood
8. *Cycles:*
Feeding cycles, daily cycles, hormonal cycles, photo-period, tides, seasons
9. *Cytology:*
The anatomy, physiology, pathology and chemistry of the cell
10. *Digestive System:*
Including digestive processes, digestive juices, dentition
11. *Distribution:*
Including comparisons between and within areas, excluding census data covering one site with no mention of distribution within the site
12. *Diving:*
Depth, speed, duration
13. *Ecology:*
An animal's relation to the environment
14. *Embryology/Obstetrics:*
Including delayed implantation, obstetrics
15. *Endocrine System:*
Hormones
16. *Evolution:*
Genetic evolution
17. *Excretory System:*
Including hepatic system, urine, osmoregulation, structures of the excretory system (e.g., liver, kidney)
18. *Exploitation:*
Sealing, killing for commercial purposes
19. *Genetics:*
Chromosomes, phenotypes, genotypes, heredity
20. *Growth:*
Morphological measurements, individual physical growth, not population growth
21. *Haematology*
22. *Hearing:*
Ear, echolocation, sonar
23. *Integument:*
Hair, skin
24. *Legislation:*
International agreements
25. *Locomotion*
26. *Management:*
Conservation
27. *Metabolism*
28. *Migration:*
Including orientation
29. *Molt*
30. *Muscular System*
31. *Nervous system:*
Nerves, brain, innervation
32. *Nutrition:*
Including food, milk, food poisoning, starvation, predation by seals, stomach contents, scat contents
33. *Parasitology*
34. *Pathology:*
Diseases, treatments, anesthetics, effects of drugs, scars, injuries, symptoms

35. *Physiology*
36. *Population dynamics:*
Including population biology, age and sex structure, vital rates, trends in population change over time
37. *Predators:*
Predation on Steller sea lions by other animals, excluding human predation
38. *Reproduction:*
Excluding embryology and obstetrics
39. *Respiratory system*
40. *Sensory system:*
Vibrissae, sense of smell, touch, taste
41. *Skeletal system*
42. *Taxonomy:*
Taxonomic procedures, classification
43. *Technology:*
Experimental procedures developed for pinniped research, pinniped deterrent devices
44. *Thermoregulation:*
Including insulation (blubber), body temperature
45. *Vision:*
Eyes, visual acuity, blindness, sensitivity
46. *Vocalization:*
Communication, vocal apparatus, audiograms
3. *Nutritional Stress – Starvation:*
Animals are unable to locate adequate amounts of food
4. *Predation – Animals:*
Animal predation (e.g., transient killer whales, sharks)
5. *Predation – Humans:*
Subsistence harvest, commercial harvest
6. *Competition with Fisheries:*
Depletion of sea lion prey, fishery effects (e.g., entanglement in nets)
7. *Migration:*
Re-distribution across range
8. *Regime Shift:*
Natural change in the abundance or distribution of sea lion prey
9. *Disease*
10. *Pollution*
11. *Trophic Cascade:*
A change in the abundance of species at trophic levels above or below sea lions which affects the abundance of species at other trophic levels
12. *Adult mortality:*
Increased adult mortality (typically coupled with long-term juvenile mortality)

It should be noted that none of these 12 hypotheses are mutually exclusive. In fact, most publications that consider hypotheses tend to consider a combination of those listed above.

HYPOTHESES TESTED

We identified 12 hypotheses (or categories of hypotheses) that have been put forward to explain the decline of Steller sea lions. They included:

1. *Juvenile mortality:*
Juvenile animals have abnormally high mortality levels
2. *Nutritional Stress – Junk Food:*
Change in the prey base altered the energy content of the prey to one that is insufficient to maintain the energy requirements of the animals

We did not categorize the papers in our annotated bibliography as addressing a hypothesis if they simply reviewed possible causes of the decline. We considered a paper as addressing a hypothesis if it formally stated the hypothesis being tested (which was rare) or if it provided a substantial body of new knowledge that was used in each paper to assess one of the 12 hypotheses listed above. Note that our listing of articles under the 'hypothesis category' does not indicate that the hypothesis was proven.

RESULTS

There are over 400 articles listed in the NMFS Steller sea lion bibliography (Strick 1993). For the years 1751-2000, we deemed 263 articles as meeting our scientific criteria (see Appendix I, II and III). Of these, 110 articles were peer-reviewed publications in international scientific journals, and 153 were other forms of publication (e.g., NMFS technical reports, unpublished reports, dissertations, etc.).

Appendices I and II list articles by authors names and date of publication, respectively, and need to be cross-referenced with Appendix III to obtain the full citations. We were unable to obtain a few articles and were therefore unable to categorize these by subject area and hypotheses tested (see Appendix IV). An amendment to our report should be undertaken when these articles are available, and as other articles are published.

Only 4 articles were published on Steller sea lions prior to the 1940s. Since then the total number of articles published per decade has risen exponentially from 4 in the 1940s to 120 in the 1990s (Fig. 1). There is a general tendency for fewer articles to be published in the primary (peer reviewed) literature compared to other forms of publication. Although, the gap in the number of articles published appears to be narrowing (Fig. 1), a wide gap is apparent between the number of pages published in the two means (primary and other – Fig. 2). To date over 9,149 pages have been printed that pertain

to Steller sea lions (1,145 pages of primary publications and 8,004 pages of other publications).

Over half of the scientific articles dealt with distribution and population dynamics (Fig. 3). The next largest areas of research pertained to ecology, census data, nutrition and behavior (over one-third of the publications). The next largest areas in order of importance were growth, reproduction, cycles, exploitation, physiology and management. Subject areas that have received low research attention (over the overall time period) include predation on Steller sea lions, captive studies, metabolism and parasitology (Fig. 3).

Of the 263 articles contained in our annotated bibliography, only 56 (21%) contained information relative to testing one of the 12 hypotheses. The most frequently addressed hypothesis concerned juvenile mortality (24 papers). This was followed by competition with fisheries, starvation and regime shifts (Fig. 4). Only 1 of the 263 articles addressed the role that killer whale predation may be playing in the decline of Steller sea lions (Fig. 4).

The relative number of articles per decade that address or provide significant information to assess hypothesized causes of the population decline are few (< 35%). However the percentage (albeit small) has been increasing over time (Fig. 5).

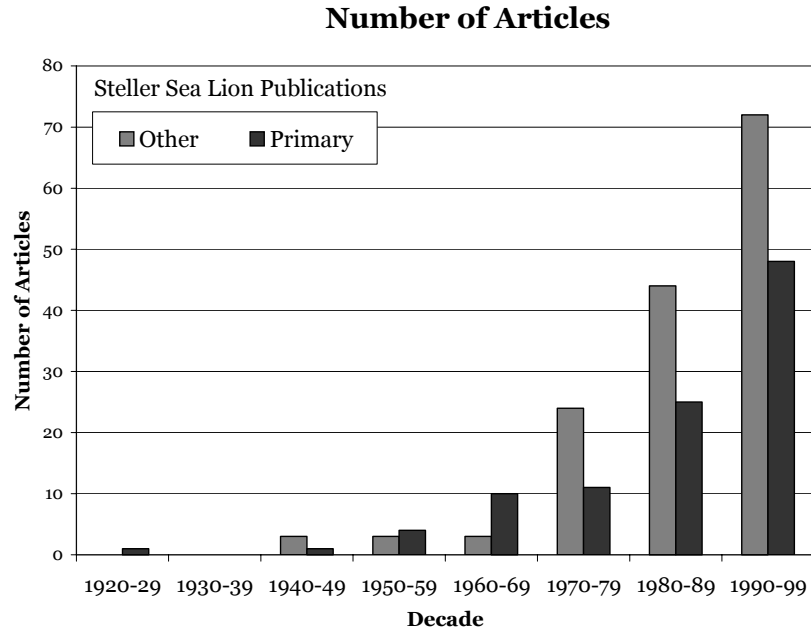


Figure 1: Total number of articles published on Steller sea lions per decade, from the 1920s to the present, of primary (black) and other forms (gray) of publications. Articles included are compiled in Appendices I and II.

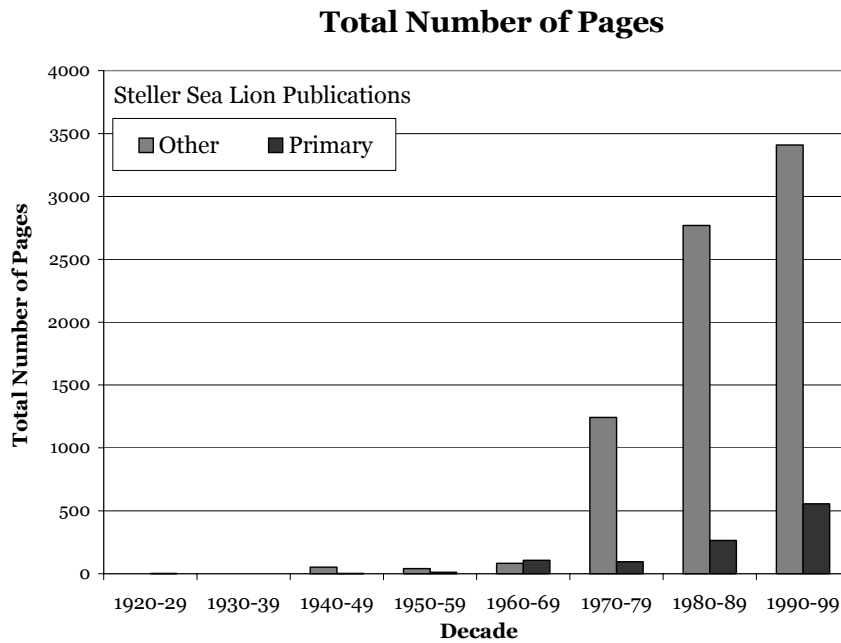


Figure 2: Total number of pages published on Steller sea lions per decade, from the 1920s to the present, of primary (black) and other forms (gray) of publications. Articles included are compiled in Appendices I and II.

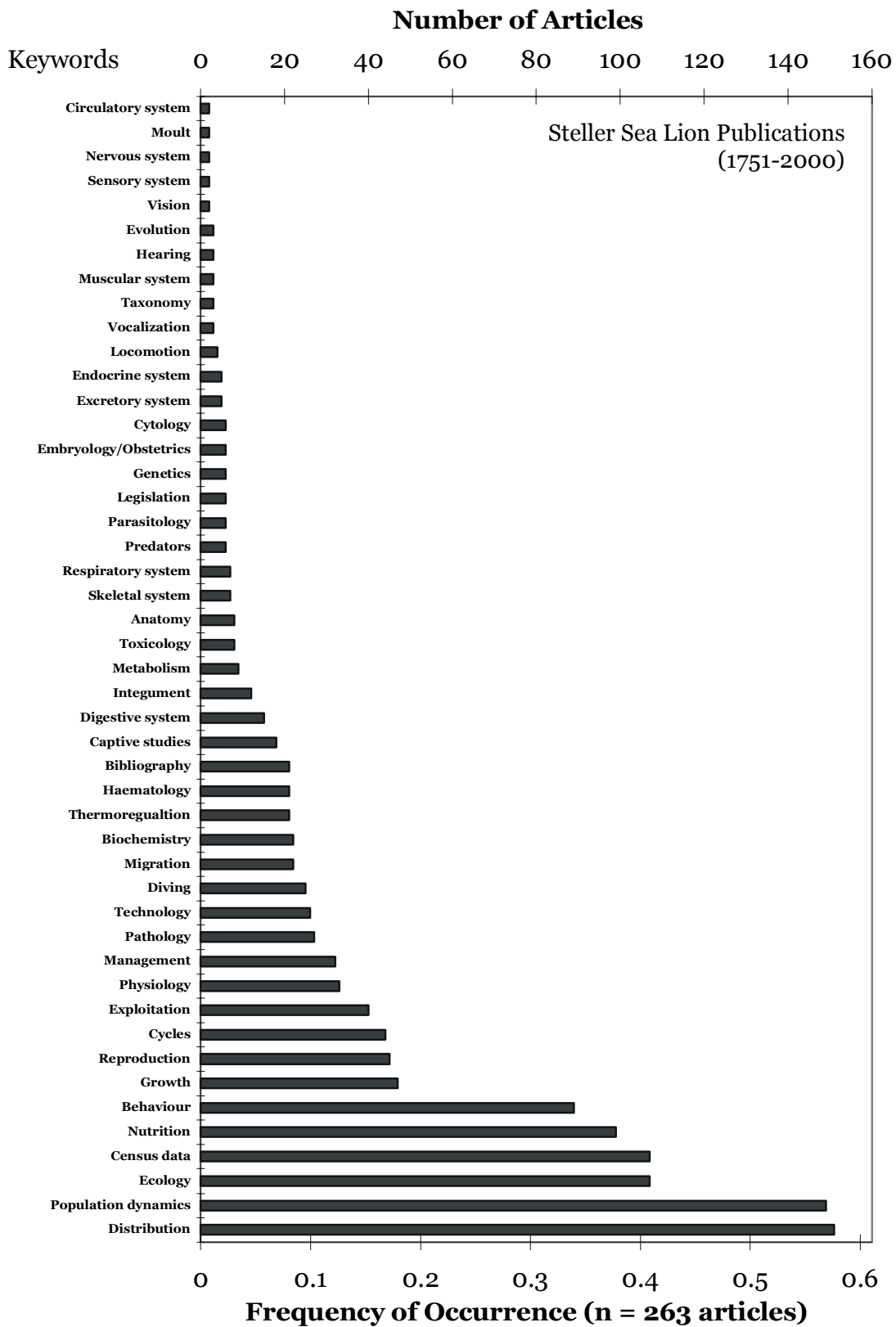


Figure 3: Keywords used to summarize 263 Steller sea lion articles published from 1751-2000. Keywords are organized by the number of articles in which the keyword appears and corresponding frequency of occurrence. Articles and keywords correspond to those contained in Appendices I and II. Note that many articles contain information pertaining to more than one keyword.

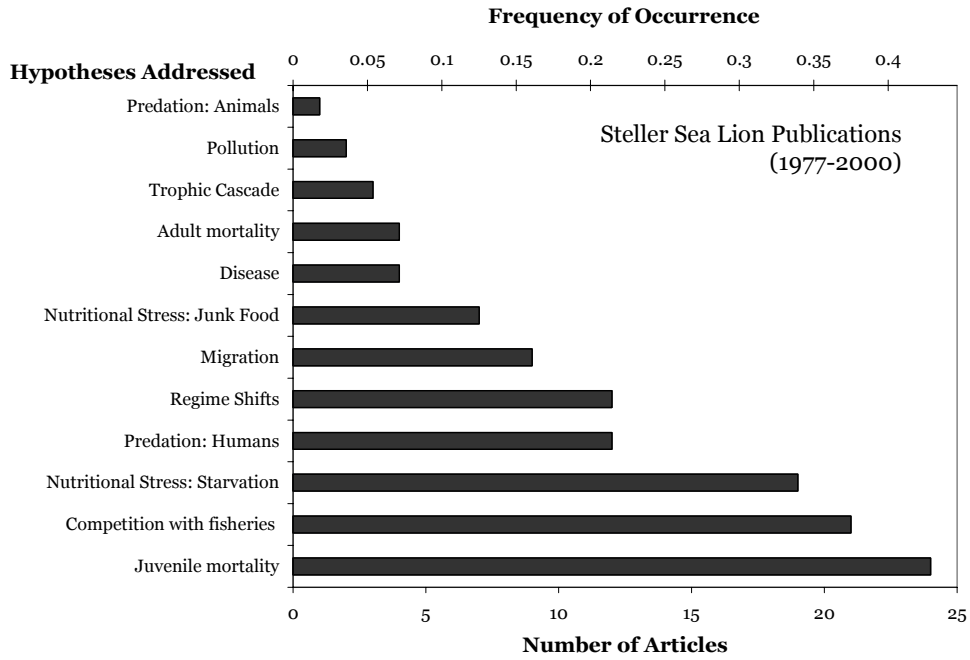


Figure 4: Number and proportion of articles that have considered hypothesized causes of the Steller sea lion decline. Each article addressed one or more hypotheses, and hypotheses addressed were non-exclusive. Hypothesis testing occurred in 56 of 263 articles considered (see Appendix I and II).

Articles that Tested Hypotheses per Total Number of Articles

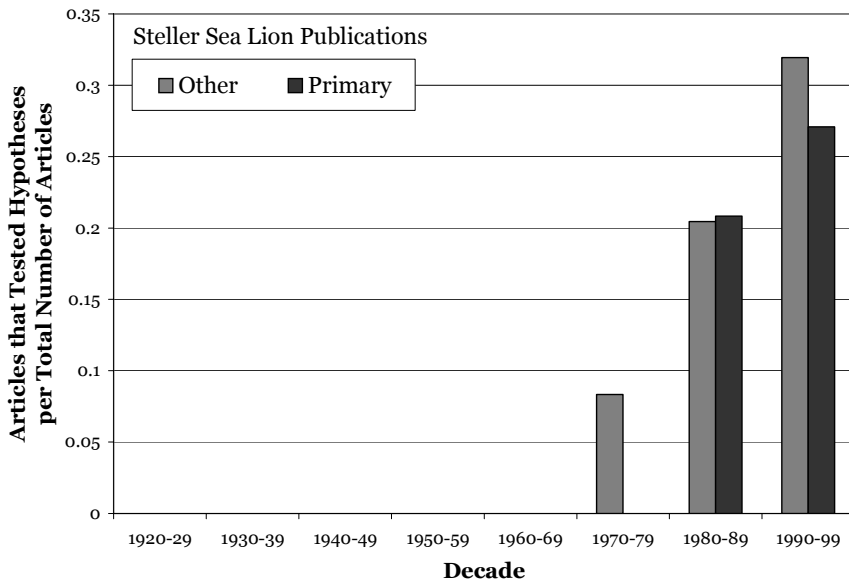


Figure 5: The proportion of all published articles that tested hypotheses from the 1920s to the present, in primary (black) and other forms (gray) of publication. Articles that tested hypotheses totaled 56 of 263 articles summarized during this period (see Appendix I and II).

DISCUSSION

Although the designation of keywords for subject areas and hypotheses tested is subjective, we believe that they provide a fair representation of the Steller sea lion literature. We interpreted the papers to the best of our ability. However, we recognize that there is some subjectivity in how we categorized the papers, and also recognize that some revisions may be required. The few published papers we were unable to obtain (Appendix IV) were not numerous enough to skew the final results.

Appendices I and II should be updated when materials become available and when new literature is published. Due to the large quantity of material we attempted to summarize, it is possible that we overlooked a few publications. Our summary could be further improved by expanding the hypotheses addressed to include the ten mechanisms outlined and analyzed by Loughlin (1998).

We found that a number of articles stated one or more hypotheses, but tended to not state whether they were supported in their discussions or conclusions. Hypotheses were rarely stated clearly, which meant that our categorization of whether a strict scientific hypothesis was tested and whether the publication contained significant information pertaining to one or more of the hypotheses was subjective at times. It should also be repeated that our categorization of papers that stated hypotheses or presented a body of relevant information is not indicative of whether there was any support for the hypotheses.

In addition to the NMFS bibliography compiled by Strick (1993), the Seward SeaLife Centre is compiling an electronic library of Steller sea lion articles. Combining the subject areas identified in our report with these two other sources would enhance the searchability of these databases.

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APPENDIX I continued

Hypotheses Addressed			
	Adult mortality		
	Trophic Cascade		
	Pollution		
	Disease		
	Regime Shifts		
	Migration		
	Competition with fisheries		
	Predation: Humans		
	Predation: Animals		
	Nutritional Stress: Starvation		
	Nutritional Stress: Junk Food		
	Juvenile mortality		
	Hypothesis testing	Z	Z
Keywords			
	Vocalization		
	Vision		
	Toxicology		
	Thermoregulation		
	Technology		
	Taxonomy		
	Skeletal system		
	Sensory system		
	Respiratory system		
	Reproduction		
	Predators		
	Population dynamics	x	x
	Physiology	x	x
	Pathology		x
	Parasitology		
	Nutrition		
	Nervous system		
	Muscular system		
	Moult		
	Migration		
	Metabolism		
	Management		
	Locomotion		
	Legislation		
	Integument		
	Hearing		
	Haematology	x	x
	Growth		
	Genetics		
	Exploitation		
	Excretory system		
	Evolution		
	Endocrine system	x	
	Embryology/Obstetrics		
	Ecology		
	Diving		
	Distribution	x	x
	Digestive system		
	Cytology		x
	Cycles		
	Circulatory system		
	Census data		
	Captive studies	x	
	Biochemistry	x	x
	Bibliography		
	Behaviour		
	Anatomy		
	No. of pages	7	8
	Publication type	P	P
	Year	1998	1997
	Reference	Zenteno Savin and Castellini 1998	Zenteno Savin et al. 1997

APPENDIX II continued

Reference	Year	Publication type	No. of pages	Keywords																																				
Lee et al. 1996	1996	P	10																																					
Merrick and Calkins 1996	1996	O	14																																					
Merrick et al. 1996	1996	O	21																																					
Moran and Wilson 1996	1996	O	19																																					
Perlov 1996	1996	P	7																																					
Shima 1996	1996	O	196																																					
Swain 1996	1996	O	31																																					
Trites and Larkin 1996	1996	P	14																																					
York et al. 1996	1996	O	34																																					
Byrd 1997	1997	O	8																																					
Byrd and Williams 1997	1997	O	13																																					
Byrd et al. 1997	1997	O	18																																					
Calkins 1997	1997	O	14																																					
Calkins and Pitcher 1997	1997	O	9																																					
Calkins et al. 1997	1997	O	24																																					
Chumbley et al. 1997	1997	O	99																																					
Gerber and VanBlaricom 1997	1997	O	53																																					
Hobson et al. 1997	1997	P	29																																					
Hood and Oro 1997	1997	P	6																																					
Loughlin 1997	1997	O	21																																					
McAllister et al. 1997	1997	O	4																																					
Merrick 1997	1997	P	13																																					
Merrick and Loughlin 1997	1997	P	11																																					
Merrick et al. 1997	1997	P	7																																					

Hypotheses Addressed

Keywords

APPENDIX II continued

Hypotheses Addressed	Adult mortality		
	Trophic Cascade		
	Pollution		
	Disease		
	Regime Shifts		
	Migration		
	Competition with fisheries		
	Predation: Humans		
	Predation: Animals		
	Nutritional Stress: Starvation		
	Nutritional Stress: Junk Food		
	Juvenile mortality		
	Hypothesis testing	N	N
	Keywords	Vocalization	
Vision			
Toxicology			
Thermoregulation		x	
Technology			
Taxonomy			
Skeletal system			
Sensory system			
Respiratory system			
Reproduction			x
Predators			
Population dynamics			x
Physiology			x
Pathology			
Parasitology			
Nutrition		x	x
Nervous system			
Muscular system			
Moult			
Migration			
Metabolism			
Management			
Locomotion			
Legislation			
Integument		x	
Hearing			
Haematology			
Growth		x	x
Genetics			
Exploitation			
Excretory system			
Evolution			
Endocrine system			
Embryology/Obstetrics			
Ecology			x
Diving			
Distribution			x
Digestive system			
Cytology			
Cycles			x
Circulatory system			
Census data			
Captive studies			
Biochemistry			
Bibliography			
Behaviour			
Anatomy			
No. of pages	7	160	
Publication type	P	O	
Year	2000	2000	
Reference	Trites and Junker 2000	Winship 2000	

APPENDIX III:

LITERATURE REVIEWED

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APPENDIX IV:

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