

SCOMM

102:2

THE PACIFIC SALMON TREATY

PART I

***The Salmon Treaty and the
Commission Process***

US/CANADA PACIFIC SALMON TREATY

- **International Treaty ratified in 1985**
- **The Pacific Salmon Commission implements the Treaty by addressing issues concerning intermingling stocks**
- **Treaty Principles (Article III):**
 1. **Each party shall conduct its fisheries and its salmon enhancement programs:**
 - **prevent overfishing and provide for optimum production**
 - **provide for benefits equivalent to the production of salmon originating —** *Equity Issue*
in its waters
 2. **The parties shall cooperate in management, research and enhancement.**
 3. **The parties shall take into account:**
 - **the reduction of interceptions**
 - **the avoiding undue disruption of existing fisheries**
 - **annual variation in stock abundance**

PACIFIC SALMON COMMISSION

ORGANIZATIONAL STRUCTURE

COMMISSION

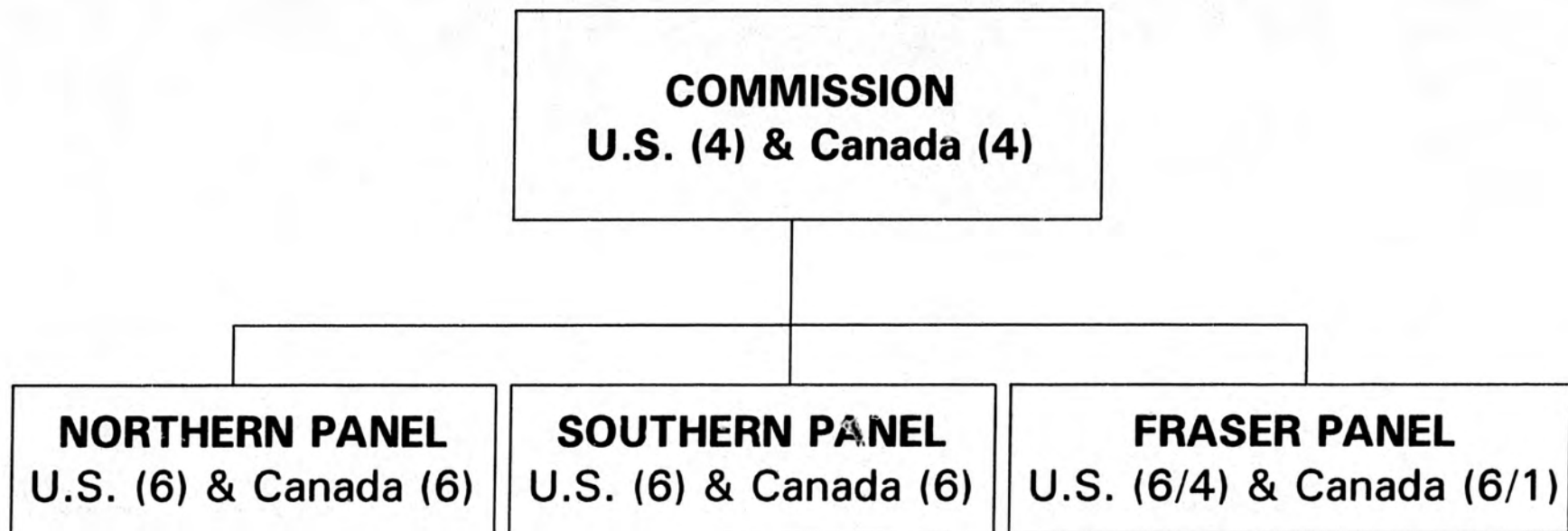
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graph TD; A[COMMISSION] --> B[UNITED STATES  
FOUR COMMISSIONERS  
(ONE VOTE)]; A --> C[CANADA  
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(ONE VOTE)]; B --> D["[UNANIMOUS VOTE REQ'D]  
- ALASKA (1 VOTE)  
- WASH/ORE (1 VOTE)  
- N.W. TRIBES (1 VOTE)  
- FED. GOVERN. (NO VOTE)"]
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FOUR COMMISSIONERS
(ONE VOTE)

CANADA
FOUR COMMISSIONERS
(ONE VOTE)

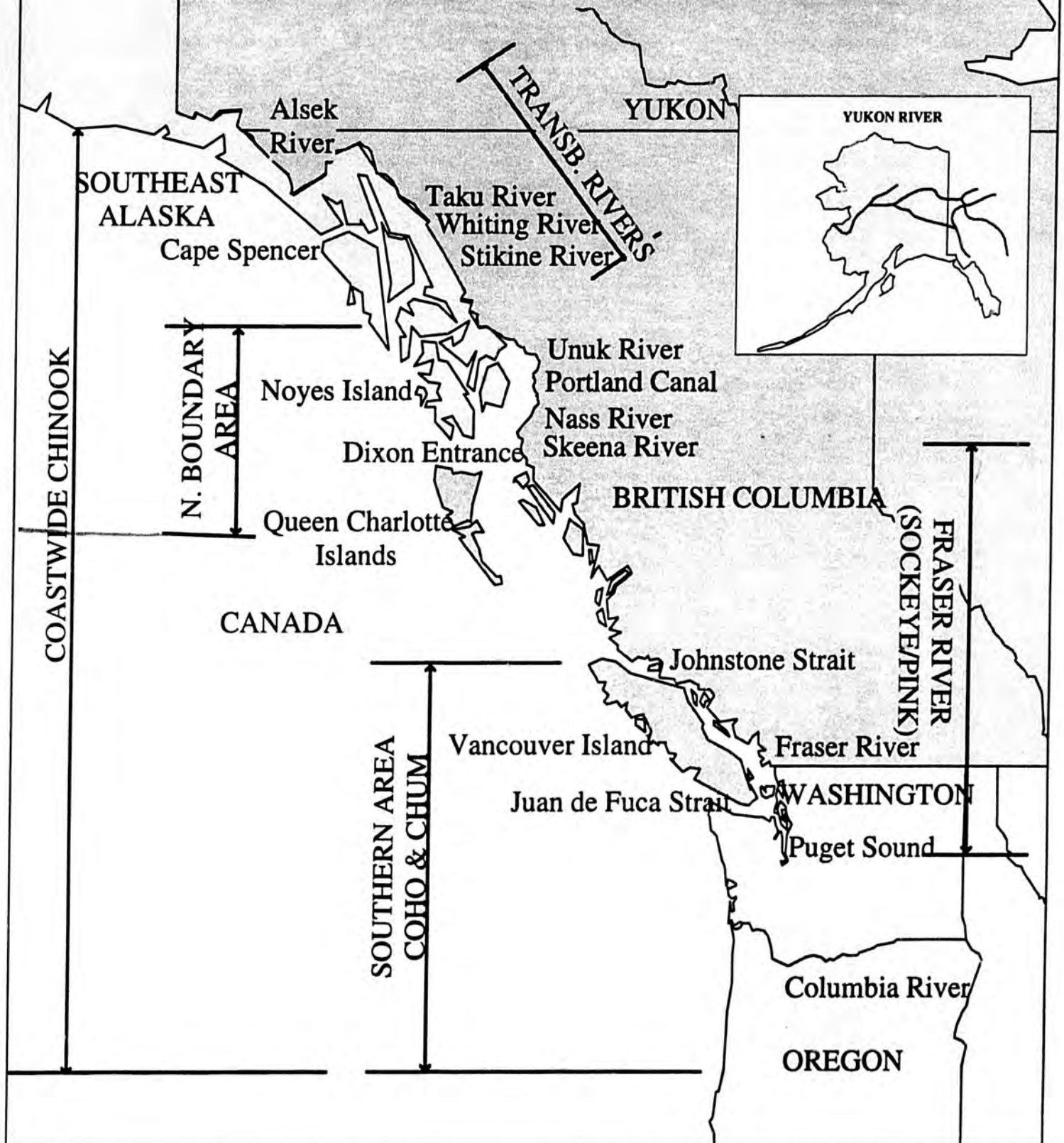
- [UNANIMOUS VOTE REQ'D]
- ALASKA (1 VOTE)
- WASH/ORE (1 VOTE)
- N.W. TRIBES (1 VOTE)
- FED. GOVERN. (NO VOTE)

1985 PACIFIC SALMON TREATY
Pacific Salmon Commission
Panel Membership



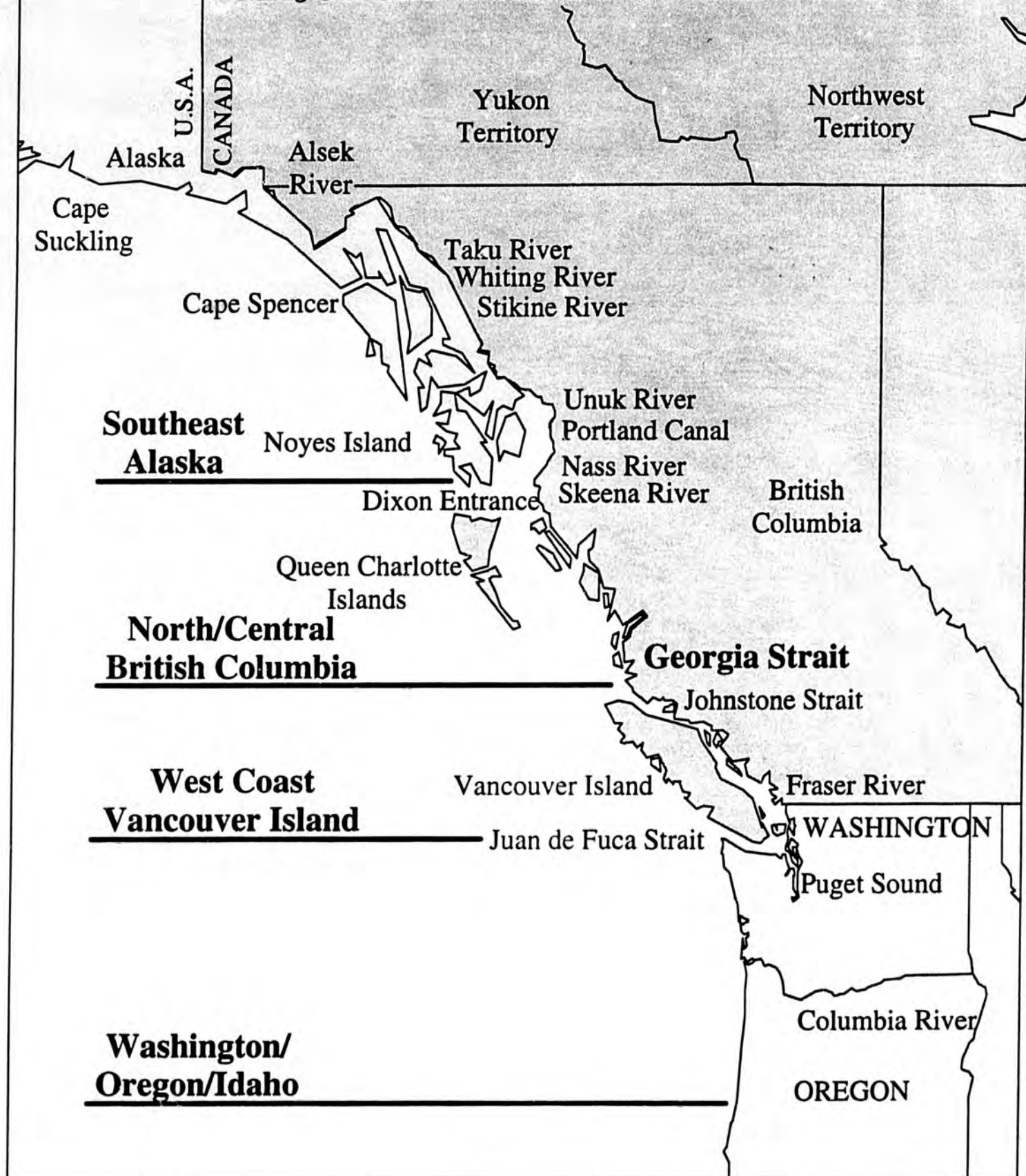
N BC - SE AK

MAJOR SALMON FISHING AREAS OF INTEREST TO THE PACIFIC SALMON COMMISSION



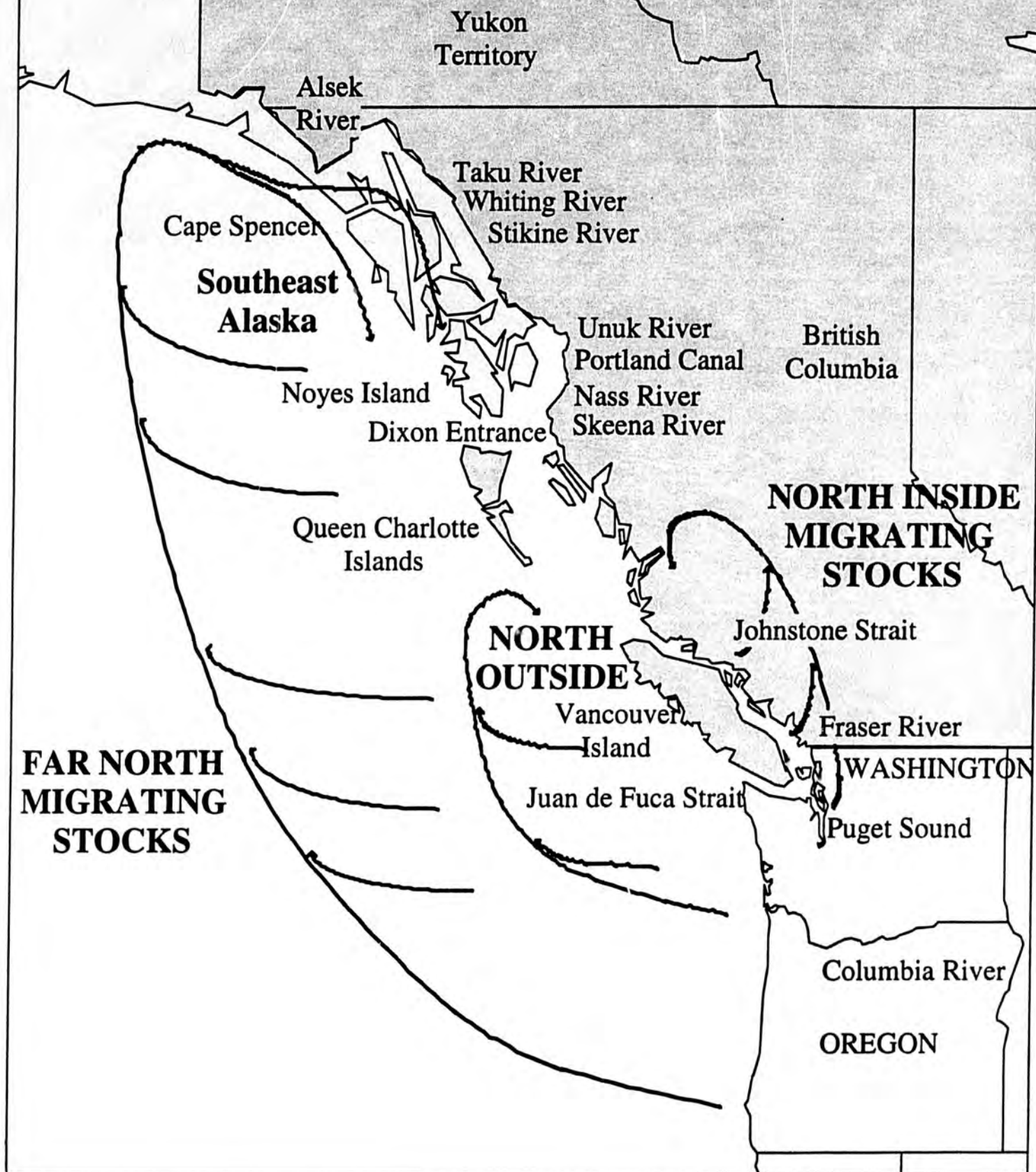
PACIFIC SALMON TREATY

MAJOR CHINOOK MANAGEMENT REGIONS

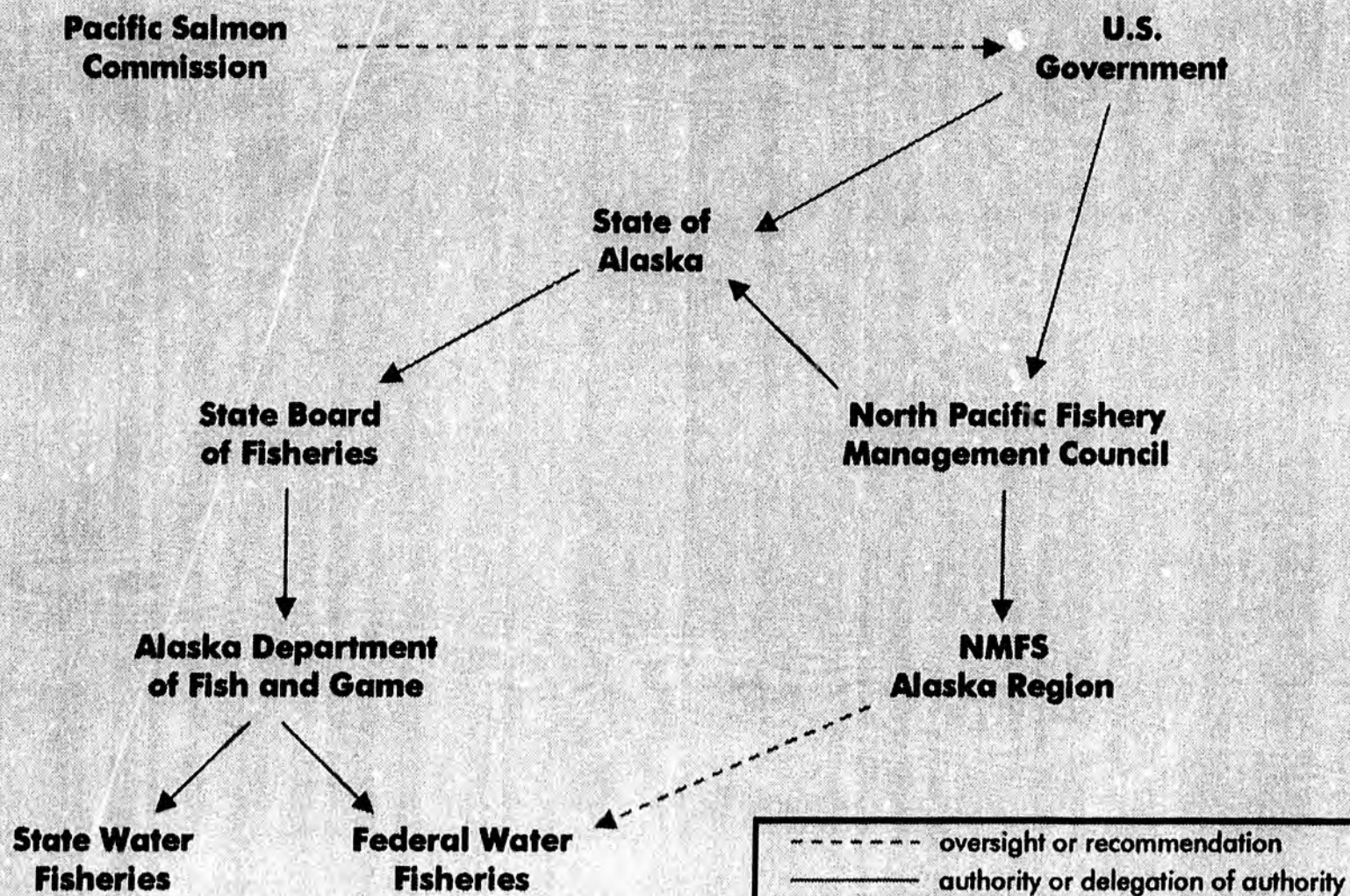


PACIFIC SALMON TREATY

MAJOR CHINOOK STOCK GROUPS



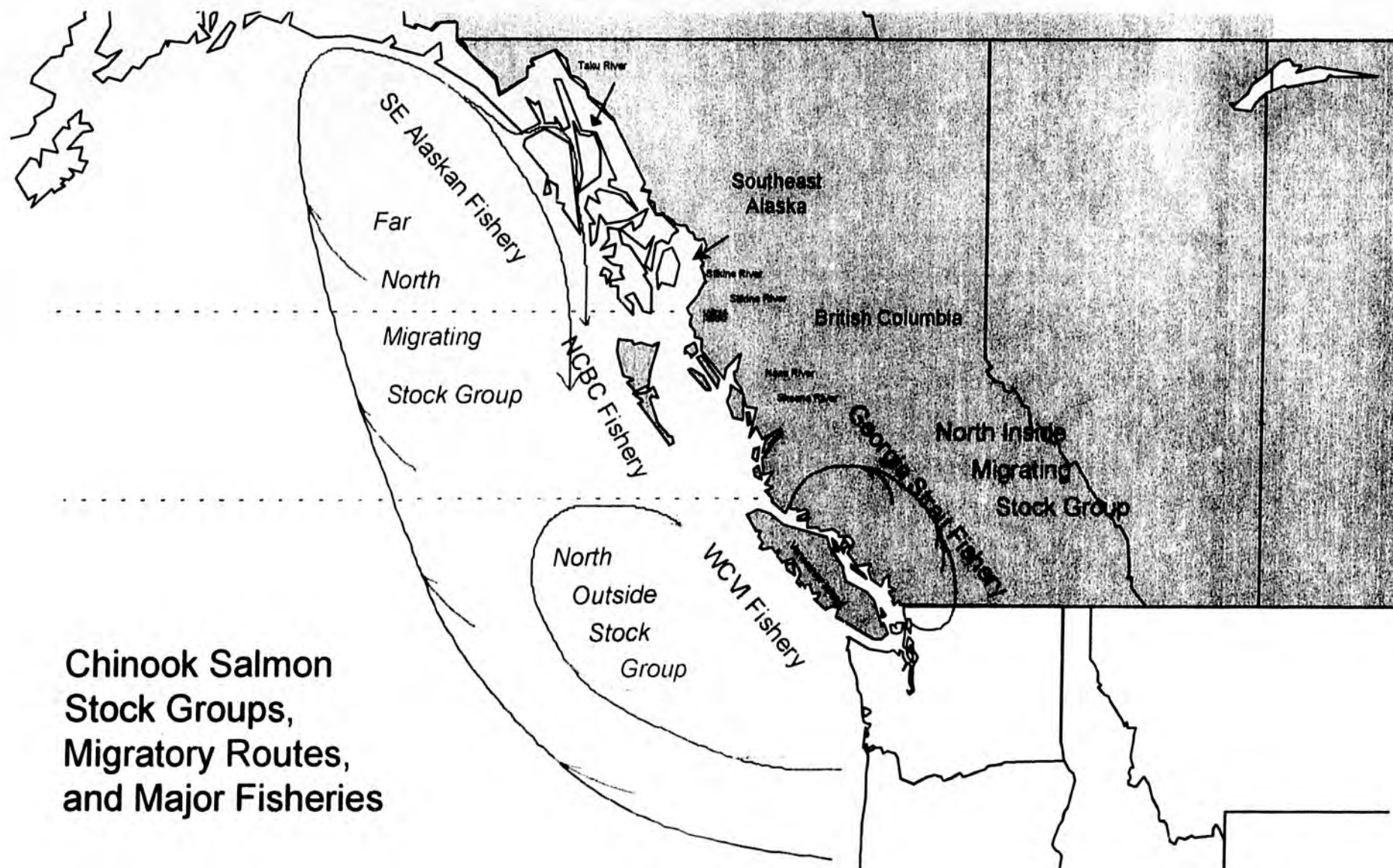
Southeast Alaska Fisheries Regulations for Pacific Salmon Commission-Affected Fisheries



PART II

Stock Aggregates and Fisheries Performance

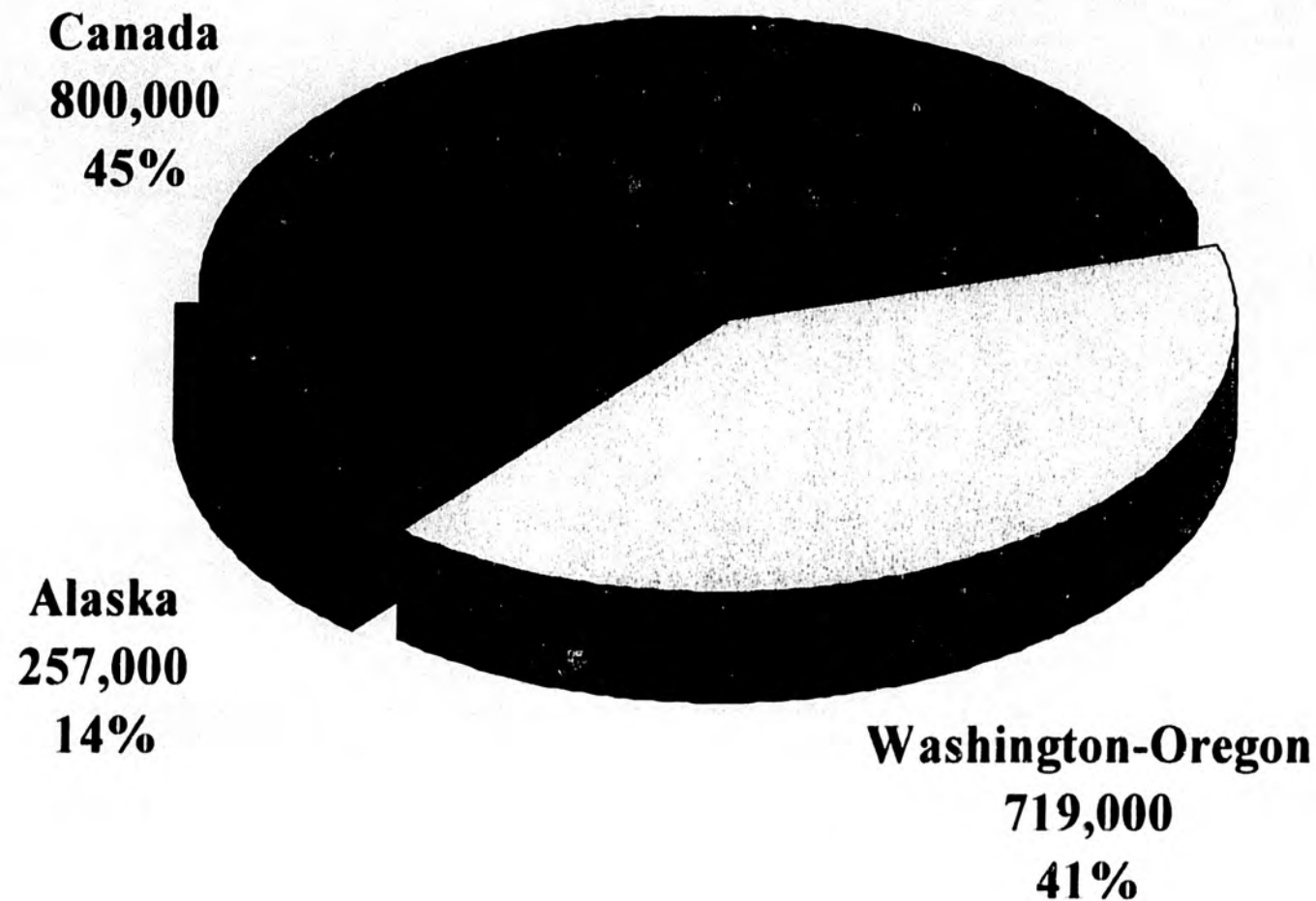
CHINOOK SALMON



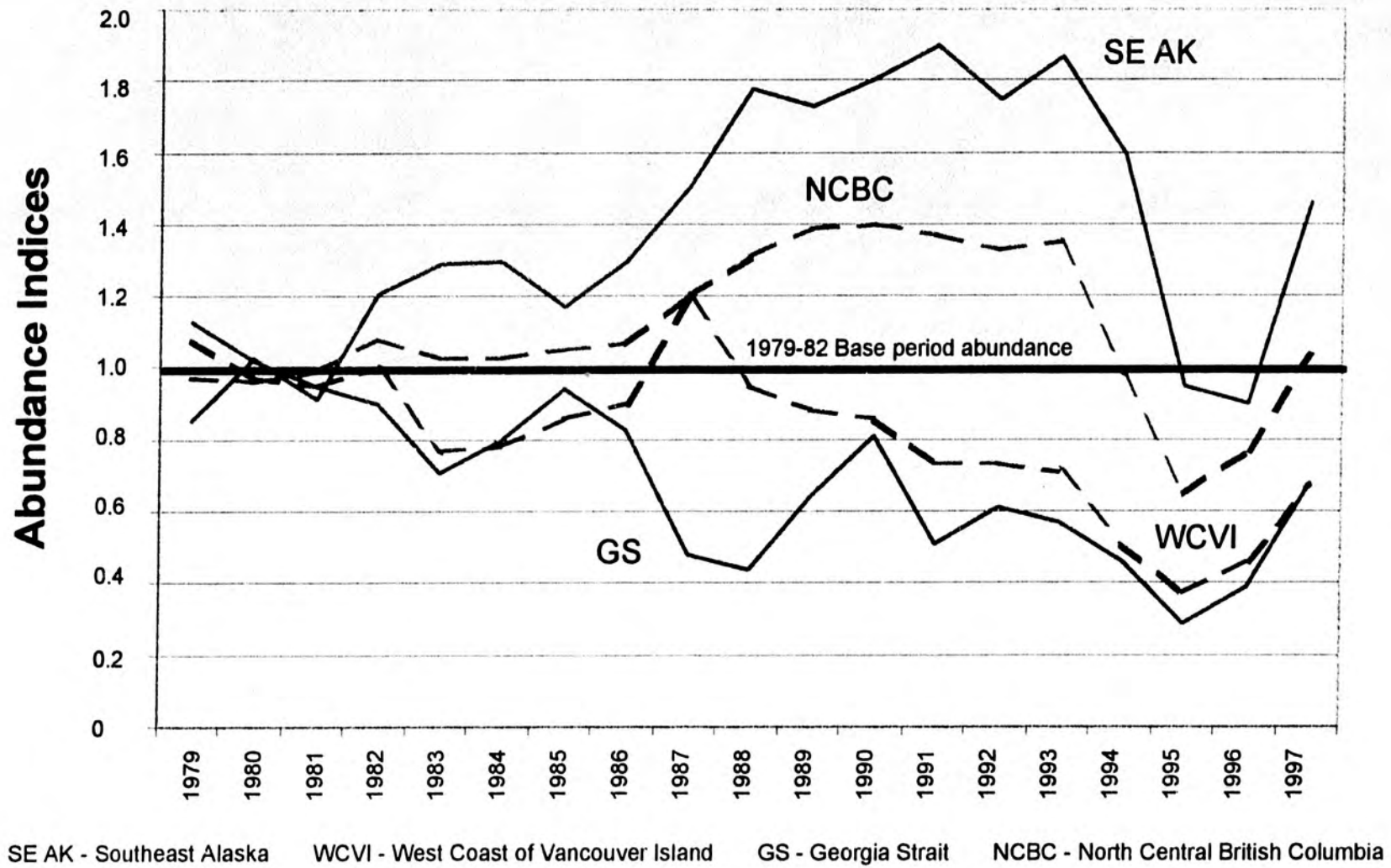
yearly

1985-1995 Average Chinook Harvest

(PSC Fisheries and Chinook Harvests)



Chinook Abundance Indices for Select Fisheries Along the Pacific Northwest Coast



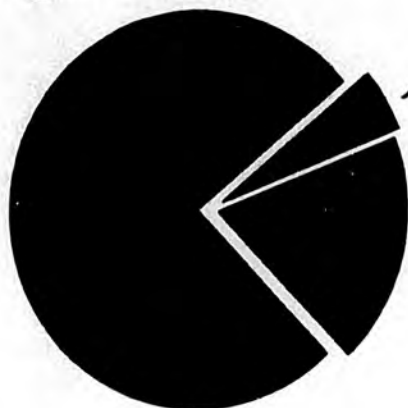
Stock Status of Naturally Spawning Chinook Salmon with the 1996 Catch in Selected Canadian and Alaskan Fisheries

■ Naturally spawning stocks not rebuilding

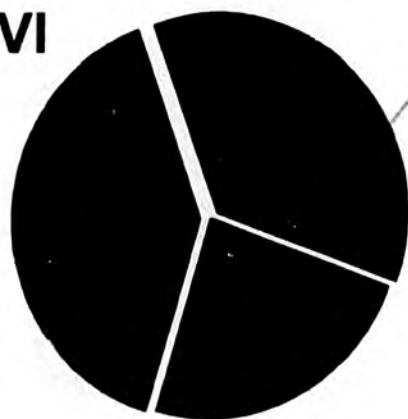
■ Naturally spawning stocks rebuilt

■ Hatchery Stocks

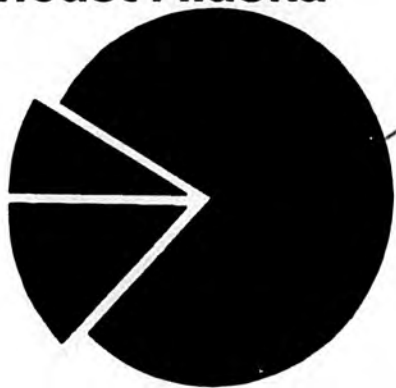
Georgia Strait



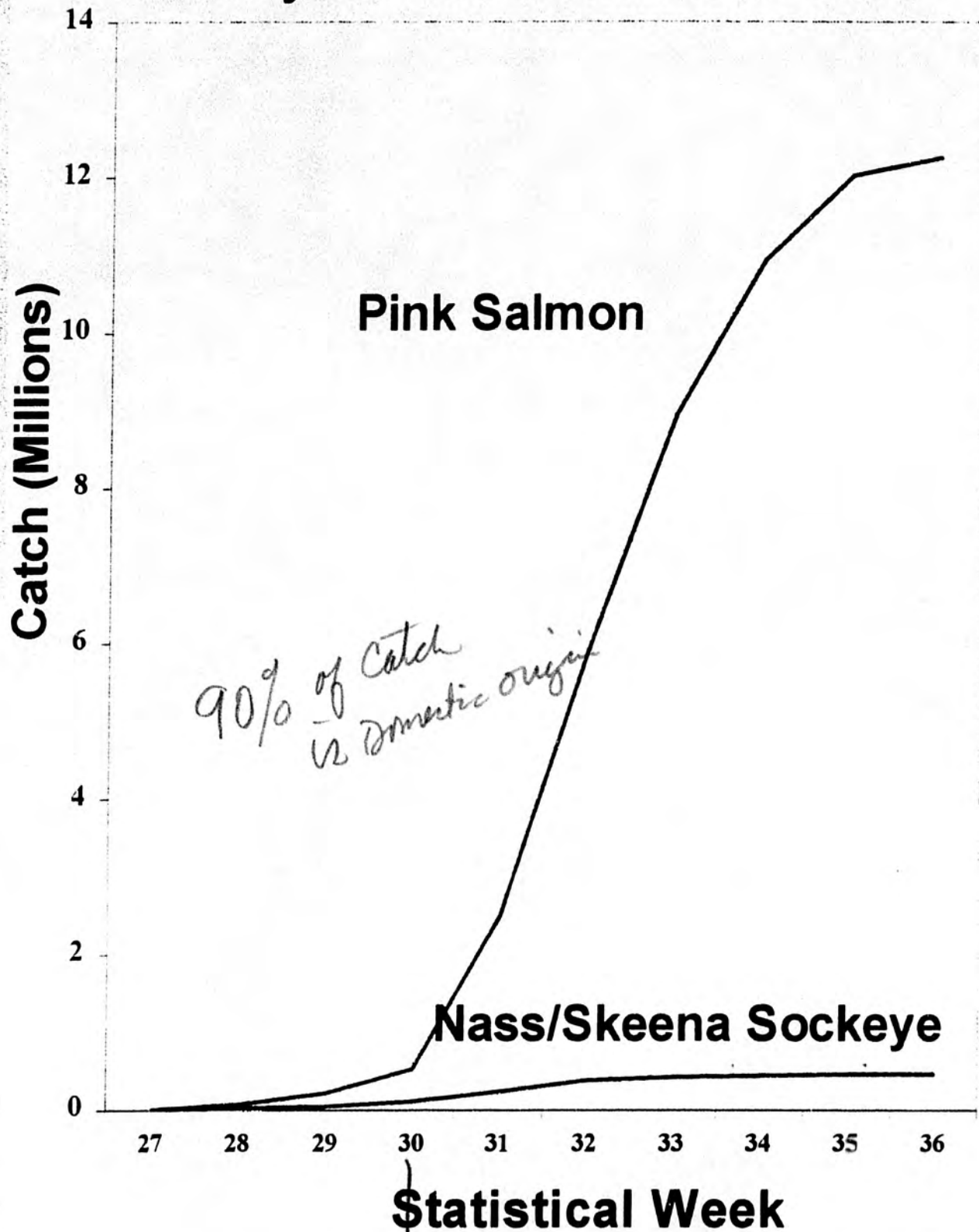
WCVI



Southeast Alaska

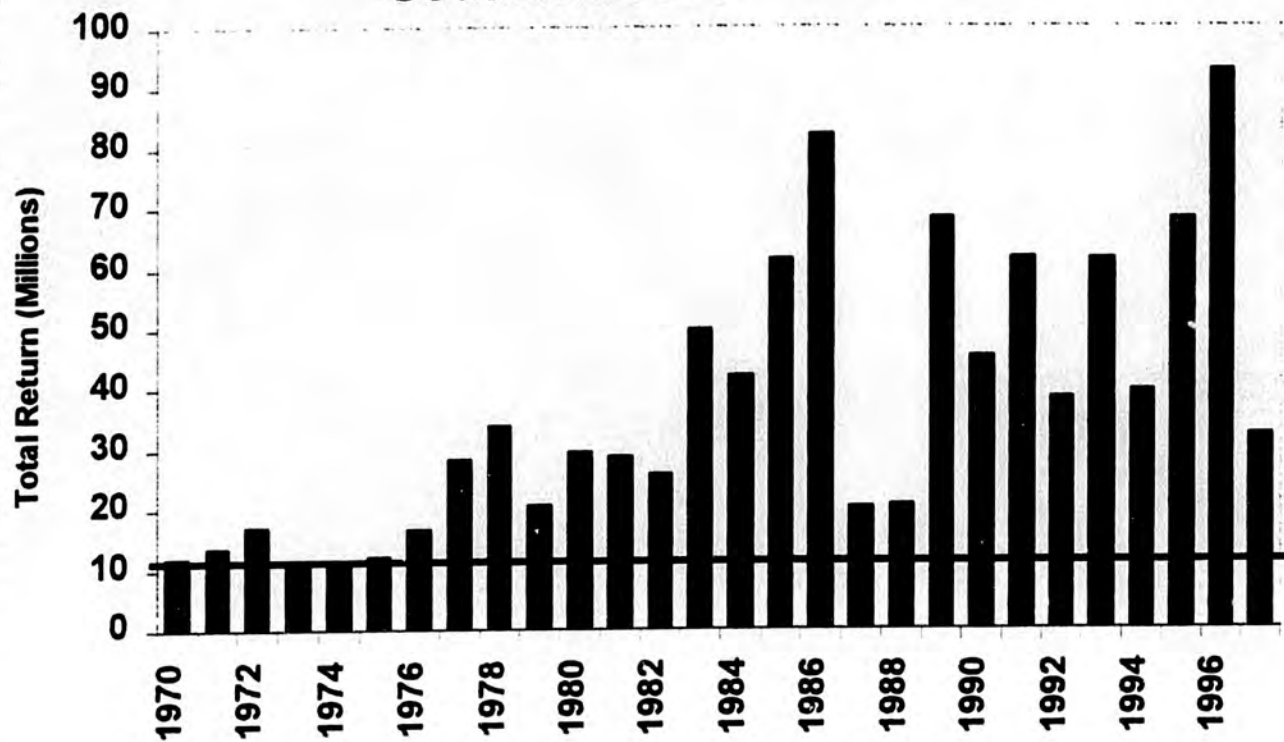


Alaska District 104 Average Cumulative Weekly Salmon Catch Since 1985

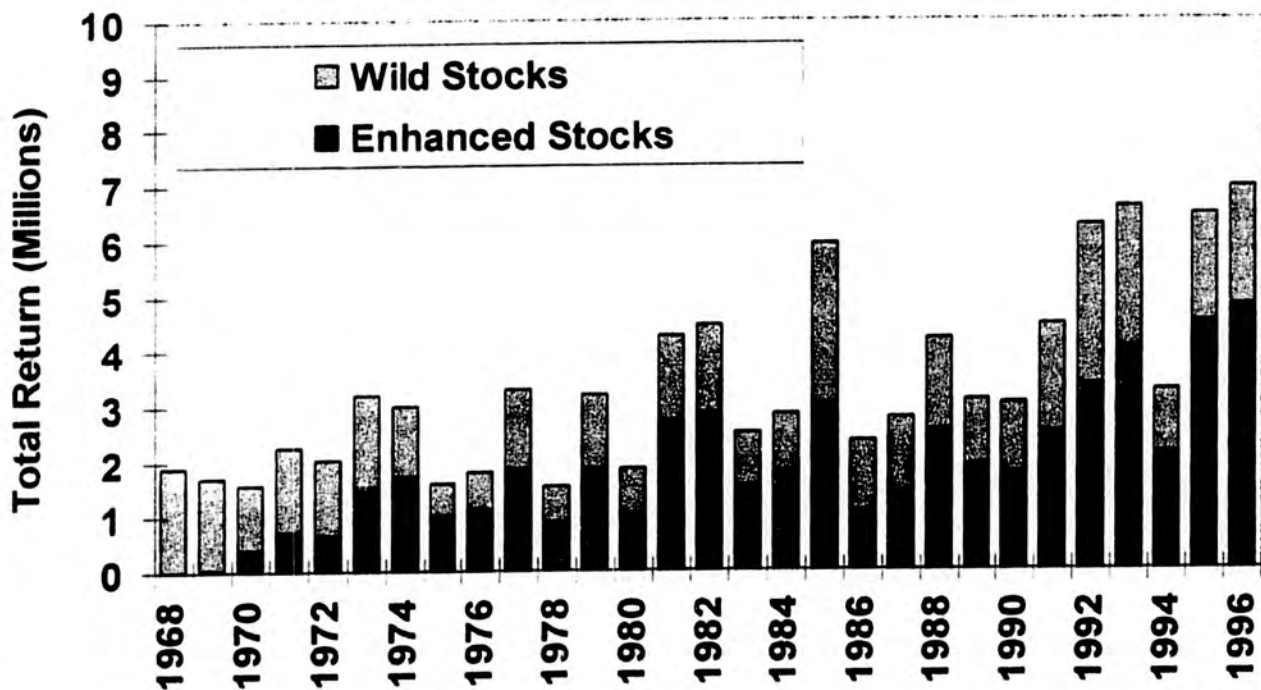


July August

Total Return of Pink Salmon to Southern Southeast Alaska

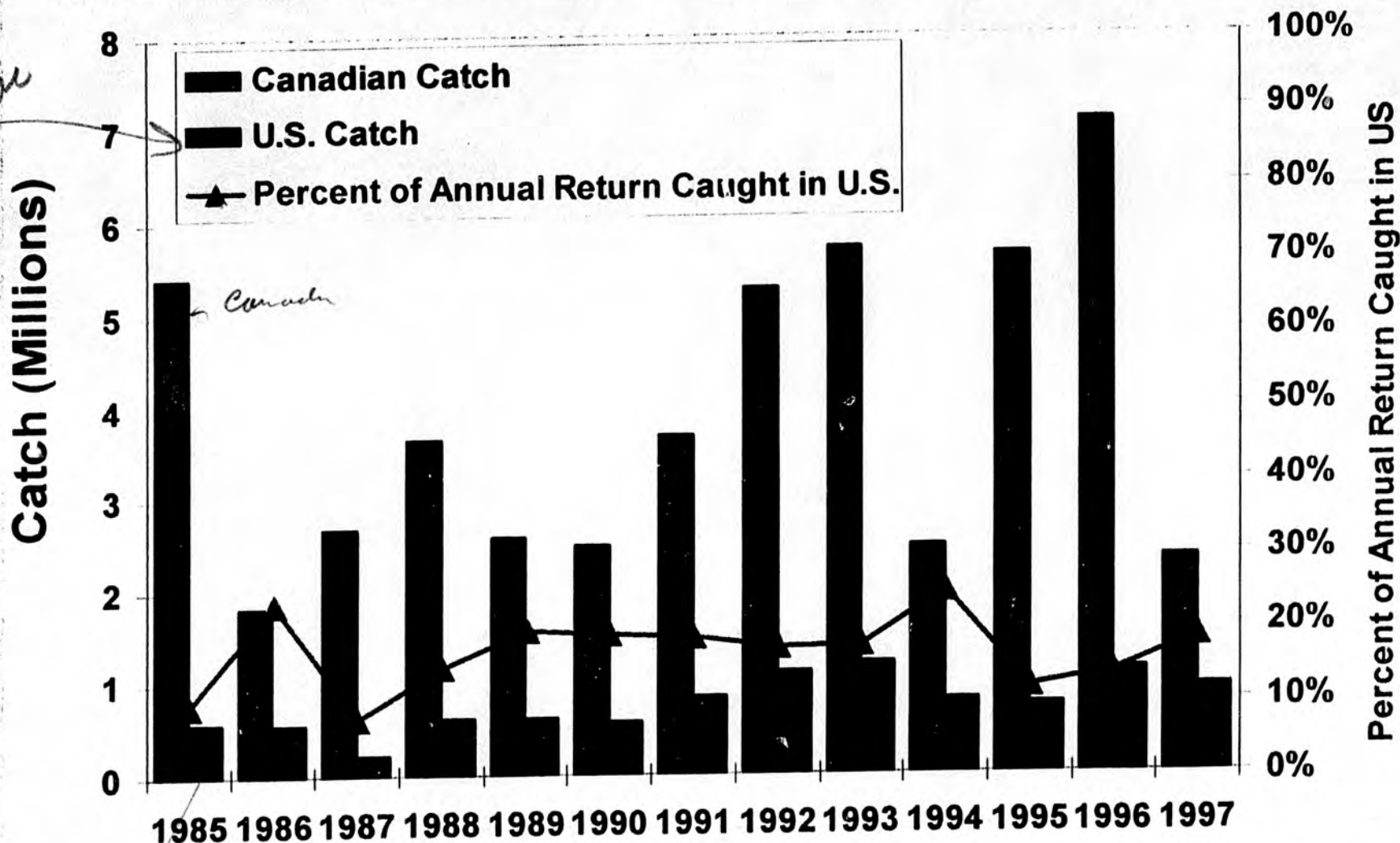


Total Return of Nass and Skeena Sockeye Salmon

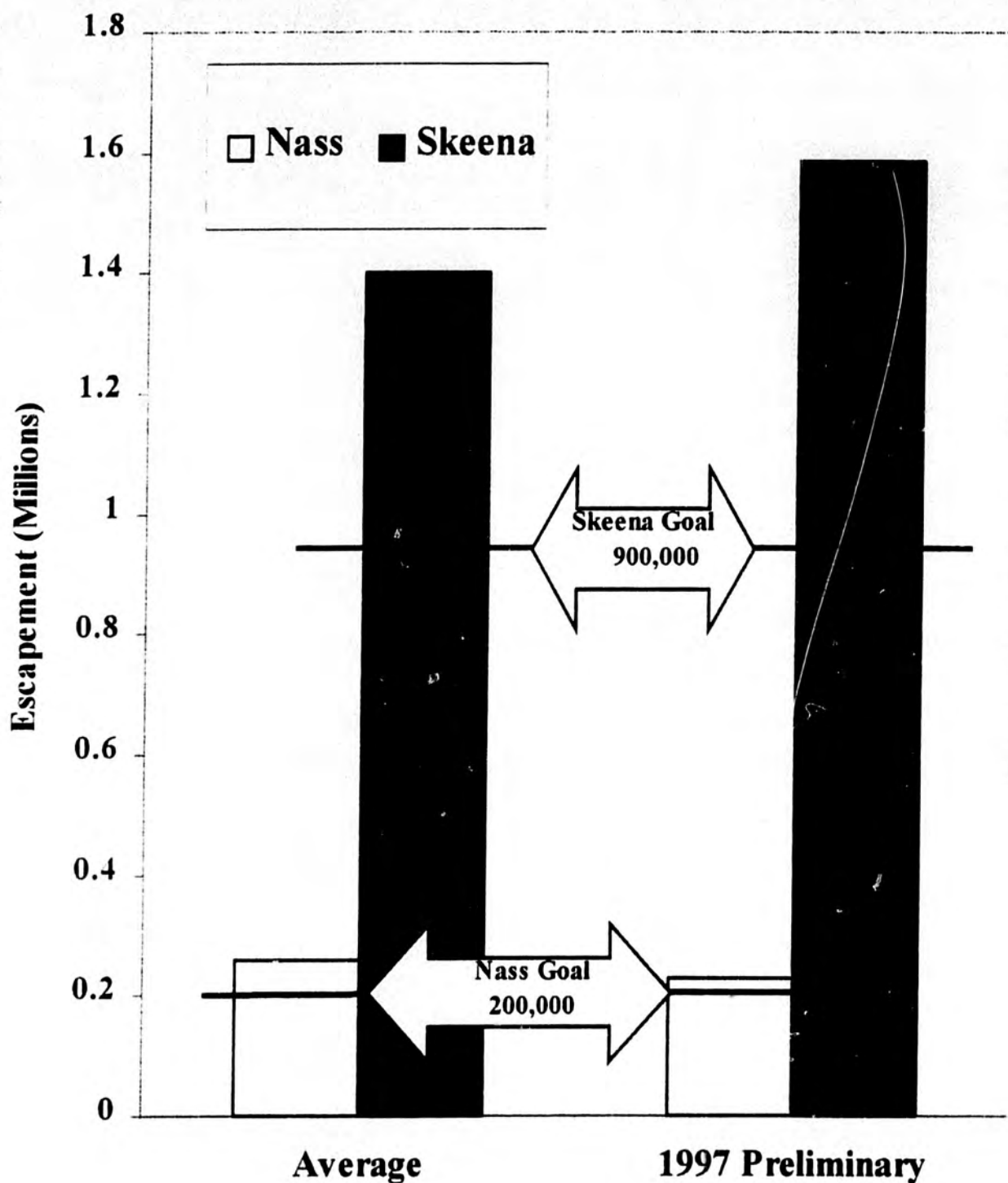


Catch of Nass/Skeena Sockeye in Canada and the U.S., and the Percent of the Total Annual Return caught in the U.S.

*Noyes
Island
Pink
Fishery*



Conservation (Escapement) of Canadian Nass and Skeena River Sockeye Salmon, Average 1985-1996 and Preliminary 1997



DEPARTMENT OF FISH AND GAME

OFFICE OF THE COMMISSIONER

P.O. BOX 25526
JUNEAU, ALASKA 99802-5526
PHONE: (907) 465-4100
FACSIMILE: (907) 465-2332

January 5, 1998

Mr. William Ruckelshaus
1000 2nd Avenue, Suite 3700
Seattle, WA 98104

Dear Mr. Ruckelshaus:

It was a pleasure meeting with you, Dr. Strangway, and representatives from Canada on December 19, 1997. I know that you are currently working with Dr. Strangway to prepare a report regarding the future of the stakeholder process. As such, I wanted to recap my main observations from the bilateral meeting of December 19th.

As you know, Alaska remains committed to the use of a stakeholder process that allows the stakeholders to talk candidly - without preconditions - about ways to resolve the dispute between Canada and Alaska arising out of the Pacific Salmon Treaty. Alaska views this process as a forum where stakeholders should be able to present proposals and explore creative solutions to resolve this dispute. Only through the open discussion of proposals will the parties find ways to narrow and resolve these issues. Alaska came to the meeting on the 19th prepared to engage in this type of dialogue and to demonstrate that we are willing and able to negotiate in good faith.

Unfortunately, the Canadian delegation came to the meeting with a set of preconditions which would effectively handcuff negotiations and defeat the purpose of the stakeholder process. In his opening statement, Mr. Chamut elaborated on the Canadian federal government's support of the stakeholder process if the process was thought to have a chance of being successful. However, this support was qualified with the caveat that the United States, as a necessary condition to resuming of the stakeholder process, had to commit to "significant and substantial transfers of fish from Alaska to Canada." In Canada's view, this would be the yardstick to measure success of the negotiations, if they were to resume. While this precondition appeared to be supported by all of the Canadian participants in the discussions, the representative of the Province of British Columbia was particularly adamant on this point. Moreover, as the talks continued, Canada made it quite clear that this "transfer of fish" was to occur in all fisheries subject to the negotiations. In essence, as a precondition to resuming talks, Canada was demanding that the United States accept Canada's narrow interpretation of Article III of the Pacific Salmon Treaty and that this be incorporated into the instructions you and Dr. Strangway would provide to the stakeholders.

As you will recall, Alaska tried several avenues to explore Canada's concerns and to persuade them that such preconditions were very counterproductive to your efforts to set the stage for renewed negotiations. We pointed out that in last years' stakeholder negotiations Alaska demonstrated considerable flexibility and the ability to compromise. In very clear terms, proposals were tabled by Alaska's stakeholders that would have significantly reduced our northern boundary fisheries at great cost to U.S. fishers. Such actions, we believe, show that our stakeholders can put meaningful proposals on the table to resolve this dispute.

In our bilateral sessions on the 19th, we provided information which showed that Canada recognized Alaska's willingness to negotiate in good faith during the previous rounds of stakeholder talks. For example, following the negotiations last year, Canadian Fisheries Minister, David Anderson, expressed to Governor Knowles Canada's acknowledgment that significant progress had been made in the north. Also included was a letter from Ives Fortier to Jim Bacon, the United States northern stakeholder chair, which expressed the view that significant progress had been made in the northern stakeholder talks.

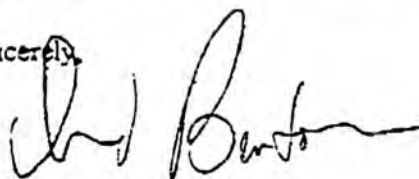
We also presented documents from the May, 1997 negotiations that demonstrated that we were close to a bilateral agreement regarding a framework for resuming the northern stakeholder negotiations in the fall. Interestingly, this agreement did not contain the kind of preconditions Canada now insists upon. We reminded the Canadians that the reason talks on this document were not concluded was the failure of the government-to-government negotiations on southern issues, which caused cessation of all further talks, not because of some irresolvable dispute over continuing talks in the north.

We also discussed with the Canadians our view that their preconditions ignored any concerns Alaska might have with the conduct of Canadian fisheries or related issues that Alaska might wish to bring to the negotiation table. And, the point was made that under an abundance-based fishery regime, the flow of fish could be in either direction depending on changes in the abundance of the stocks over time. As you no doubt observed, these arguments were not persuasive to Canada and they were unwilling to move off their hard-line precondition. In subsequent conversations I have had with Canadian officials, I would have to say that their position remains largely the same as it was on the 19th.

As we have said on many occasions, Alaska supports the use of a stakeholder process to resolve this dispute, and the meeting of December 19 was very unfortunate when you compare it to what was being said by the Canadians in May of 1997. However, the preconditions set forth by Canada do not create the climate necessary for such a process to be successful. I certainly wish it were otherwise.

I also want to take this opportunity to thank you for your hard work trying to restart the stakeholder negotiations. I know that both you and Dr. Strangway put in long hours in your efforts. If there is anything I can do to be of further service, please feel free to call.

Sincerely,



David Benton
PSC Commissioner for Alaska

cc: Governor Tony Knowles
Frank Rue, Commissioner
Jim Pipkin
Mary Beth West

Pollock's effect on marine mammals topic in joint meeting

By Charles Bingham

Alaska Newspapers

ANCHORAGE — The Steller sea lion has seen its numbers slip so much in recent years various stocks of the marine mammal are now on endangered and threatened species lists.

But trying to track the reasons for the decline is like piecing together a jigsaw puzzle, University of British Columbia professor Dr. Andrew Trites told a joint meeting of the Alaska Board of Fisheries and the North Pacific Fishery Management Council Feb. 3 at Anchorage's Hilton Hotel.

Trites said Alaska's western stock of the Steller sea lion (Prince William Sound to the Bering Sea) began to experience a sharp decline in 1974 and that stock is now on the endangered list. The eastern stock (Southeast Alaska) is slowly growing, but remains on the threatened list.

"There are several possible rea-

sons for this, it's like a jigsaw puzzle," Trites said. "Is it overfishing? Or the rise of pollock? We feel pollock is central to the problem, but we're not sure if it's too many or too few."

Trites said six Steller sea lions in captivity at the Vancouver Aquarium served as test subjects to a diet study. For some periods the captive sea lions were fed a diverse diet of herring, Atka mackerel, pollock, squid and other forage foods commonly found in Alaska. During other periods the sea lions were fed a diet heavy in pollock, which over the past 20-40 years has become the dominant staple food of the western stock of Steller sea lions.

Trites said during the pollock diets, the sea lions actually ate more food but lost as much as a pound a day. In fact, during some of the pollock periods the diets had to be switched back to herring because the sea lions lost too much weight.

"Is pollock a junk food?" Trites asked. "In areas where pollock is

strong, the sea lions are not as healthy. The strongest stocks (of sea lions) have diverse diets. Not only are they losing weight, but they go into a metabolic depression, so they lose twice."

Trites said there's no real sign the sea lions are starving, but animals in the 1970s were bigger than in the 1980s. He also said there are more fetuses aborted in the winter now. Trites also said there are similar declines in sea birds, sea otters, harbor seals and Northern fur seals, all starting about the mid-1970s.

Unfortunately, there are so many variables that even the decline of the Steller sea lion can't be officially linked to the rise of pollock, Trites said. He said other reasons to consider include the end of commercial whaling in the 1950s, or it could be industrial development or overfishing of a forage fish that shifted the ecosystem as larger animals were forced to alter their diets.

"The trouble may not be in the Bering Sea, it could be in the Gulf

of Alaska," Trites said. "The Steller sea lions range from northern Japan to California. We're trying to get a better understanding of how animals use the ocean food web, and what happened to cause the shift."

Trites' discussion of Steller sea lion research was just one of six main topics on Tuesday's meeting agenda. Members of the two fishery groups also heard reports on Bering Sea/Aleutian crab issues, a scallop fishery management plan, halibut management plans, groundfish issues, and issues concerning salmon bycatch reporting during the Bering Sea/Aleutian Islands groundfish seasons.

Even though they manage different fisheries, the two groups meet periodically to discuss areas

where they have similar concerns. Several years ago the two groups drifted apart, but now they're back to working with each other on key issues.

"We actually have a working relationship," said Dr. John White of Bethel, the chairman of the Alaska Board of Fisheries. "This helps keep us together on cross-jurisdictional issues."

"There are a lot of resources we're both interacting on," said Robin Samuelson of Dillingham, a member of the North Pacific Fishery Management Council. "They're mandated on some things, and we're mandated with different concerns. I think both fisheries benefit from a much better relationship."

Dr. Trites is the Research Director of the North Pacific Universities Marine Mammal Research Consortium which is undertaking long term research into the interactions between marine mammals and fisheries. He is also an Assistant Professor and Director of the Marine Mammal Research Unit at the University of British Columbia. His interests include the population biology, bioenergetics and censusing of seals, sea lions, sea otters, whales and dolphins, and involve a combination of field studies, captive studies and computer studies (data analysis and simulation modelling). Current research includes developing an ecosystem model of the Bering Sea, analyzing the long term dynamics of pinnipeds in the North Pacific, and estimating the dietary needs of marine mammals relative to commercial fishing activities.

Scientists puzzling out reasons for Stellar sea lion decline

By Charles Bingham
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so that a correction factor could be developed to calculate total abundance. In 1993 Congress began providing funds to the Alaska Department of Fish and Game, through the National Oceanic and Atmospheric Administration, to carry out research to investigate factors responsible for the harbor seal decline. These funds have supported studies of harbor seal behavior on land and at sea, physiology, disease, population dynamics, and trophic relationships.

Numerous research efforts on harbor seals continued in 1997. For example, researchers from the National Marine Fisheries Service and Alaska Department of Fish and Game satellite tagged 10 pups at Tugidak Island and 12 from Prince William Sound to study pup movement and behavior. Biologists from both groups also captured harbor seals and took samples of blood, blubber, whiskers, and skin to assess body condition, look for indications of disease or stress, and to help determine diet and stock structure. In collaboration with scientists at the National Marine Mammal Laboratory, a program is being developed to study fine structure of teeth as an indicator of sexual maturity and nutritional status. Work continues on the identification of the genetic structure of harbor seals in Alaska using mitochondrial DNA and micro-satellite DNA as a means of identifying biological stocks.

In collaboration with the Alaska Department of Fish and Game, the Alaska Native Harbor Seal Commission has undertaken a biosampling program that involves the collection and analysis of samples from harbor seals harvested by Alaska Native subsistence hunters. The University of Alaska also collaborated with the Department on studies of changes in the demography and pupping phenology of harbor seals on Tugidak Island.

Steller Sea Lion (*Eumetopias jubatus*)

Steller sea lions occur along the northern rim of the North Pacific Ocean from southern California to Hokkaido, Japan. About three-quarters of all Steller sea lions pup and haul out on U.S. beaches, with most animals occurring in the Gulf of Alaska and the

Aleutian Islands. Over the past 30 years, Steller sea lion abundance has declined precipitously throughout most of the western part of the species' range (see Table 4). In this region, counts have decreased by more than 80 percent since the 1960s, and at some sites, sea lions are in danger of disappearing altogether. Because of these trends, the National Marine Fisheries Service designated the Steller sea lion as threatened under the Endangered Species Act in 1990.

Although the cause of the species' decline is unclear, a leading hypothesis is that available prey has either decreased in abundance or changed in composition. This, in turn, is thought to have caused an increase in sea lion mortality, particularly among juveniles. Steller sea lions feed on a wide variety of fish, mollusks, and crustaceans. Because a number of key prey species — such as pollock, Atka mackerel, salmon, and flat fishes — are subject to intense commercial fishing in Alaska waters and elsewhere, commercial fisheries are suspected as a significant factor affecting prey availability for sea lions.

Other factors that have affected sea lions to varying degrees in at least some areas include incidental taking by foreign and joint-venture trawl fisheries off Alaska between the late 1960s and late 1980s, human disturbance at haul-out sites, deliberate shooting by fishermen, a commercial sea lion harvest in parts of Alaska from the 1950s to the early 1970s, a sea lion culling program in British Columbia from about 1900 to 1960 to reduce predation on fish stocks, and subsistence harvests in Alaska and Russia.

The National Marine Fisheries Service has lead responsibility for the recovery of Steller sea lions under the Marine Mammal Protection Act and the Endangered Species Act. At the recommendation of the Marine Mammal Commission, the Service established the Steller Sea Lion Recovery Team in 1990 and adopted the Steller Sea Lion Recovery Plan in 1991 to help guide recovery efforts. Key partners in the Service's recovery program have included the Alaska Department of Fish and Game, the Marine Mammal Commission, the North Pacific Fishery Management Council, and the North Pacific Universities Marine Mammal Research Consortium. The latter group, a consortium of academic institutions in Alaska, British Columbia, Oregon, and Washington,

was established in 1992 at the request of fishing industries to investigate the cause of the decline of Steller sea lions.

To address the decline of Steller sea lions, the Service, in cooperation with other agencies and groups, has mounted an intensive research effort to monitor the status of sea lion populations and to identify the cause of the decline. To mitigate direct and indirect effects of commercial fisheries, the Service established regulations in 1992 and 1993 to (1) prohibit discharges of firearms within 100 yards of a sea lion, (2) prohibit (with some exceptions) the operation of vessels within 3 nautical miles (nmi) of major Alaska rookeries, (3) establish no-trawl zones within 10 nmi of many major sea lion rookeries in Alaska and within 20 nmi of major rookeries in the Gulf of Alaska and eastern Aleutian Islands to protect sea lion foraging areas, and (4) adjust quotas for fishing areas to prevent concentrated fishing effort in foraging areas beyond the no-trawl zones around major haul-out sites. In 1993 the Service also designated all major rookeries and adjacent waters under U.S. jurisdiction as critical habitat under the Endangered Species Act. The designated areas include waters within 20 nmi of major haul-out sites in the western part of the species' range and within 3 nmi of sites in the eastern part.

Despite these efforts, the species' decline in the western portion of its range has continued. Recent efforts to address this situation are described below.

Steller Sea Lion Status under the Endangered Species Act

As noted above, the National Marine Fisheries Service designated Steller sea lions as threatened under the Endangered Species Act in 1990. The designation applied to Steller sea lions throughout their range and treated the species as a single population. Subsequent research, however, indicates that Steller sea lions are composed of at least two distinct stocks, one east and one west of Cape Suckling, Alaska, in the north central Gulf of Alaska near Prince William Sound.

Among other things, the research indicates that there are genetic differences between sea lions east and west of Cape Suckling and that there is little exchange of animals between haul-out sites and rookeries east and west of that point. With the exception of a marked decline in sea lion numbers at the species' southernmost rookeries in California, the eastern stock also appears to be relatively stable or increasing slightly, whereas rookeries and haul-out sites west of Cape Suckling generally have experienced steep, steady declines.

Based on this new information, the Steller Sea Lion Recovery Team and the Marine Mammal Commission recommended that the Service revise the species' listing status under the Endangered Species Act to recognize two stocks of Steller sea lions — an eastern stock that is threatened, and a western stock that is endangered. The Service agreed that the change appeared warranted and published a proposed rule in the *Federal Register* on 4 October 1995 to make the change. As noted in the previous annual report, on 11 January 1996 the Commission commented to Service in support of the proposed rule.

On 5 May 1997 the Service published final rules changing the status of Steller sea lions under the Act to designate the eastern stock as threatened and the western stock as endangered. In doing so, the Service noted that it did not appear necessary to modify designated critical habitat for Steller sea lions or existing protection measures; however, it also indicated that it was taking steps to reassess the effectiveness of existing protective measures with a view toward improving them.

Research on Steller Sea Lions

To provide an informed basis for identifying, evaluating, and justifying Steller sea lion conservation measures, the National Marine Fisheries Service, the Alaska Department of Fish and Game, the North Pacific Universities Marine Mammal Research Consortium, and others have developed a broad cooperative research program to monitor population trends and elucidate the cause or causes of the decline.

Table 4. Steller sea lion population estimates, 1960s-1994
 († = estimates excluding pups; ‡ = estimates including pups)

Area	1960s	1970s	1985	1989	1994	% Difference 1960s to 1994
Western Stock						
Russia†	41,000- 52,300	—	—	10,000	—	—
Aleutian Islands‡	127,300	115,700	78,400	24,400	19,000	-85%
Bering Sea‡	11,600	5,200	3,800	1,200	2,200	-81%
Gulf of Alaska‡	88,700	70,700	48,900	40,600	22,000	-75%
Total Western Stock‡ (U.S. areas only)	227,600	191,600	131,100	66,200	43,200	-81%
Eastern Stock						
Southeast Alaska‡	9,000	10,300	10,300	15,800	14,600	+62%
British Columbia†	11,500	6,100	6,100	6,100	8,100	-30%
Oregon & California‡	10,300	6,400	6,700	6,800	9,300	-10%
Total Eastern Stock‡ (U.S. area only)	19,300	16,700	17,000	22,600	23,900	+24%

Sources:

- Loughlin, T.R., A.S. Perlov, and V.A. Vladimirov. 1992. Range-wide estimation of total abundance of Steller sea lions in 1989. *Marine Mammal Science* 8:220-239.
- Small, R.J., and D.P. DeMaster. 1995. Alaska marine mammal stock assessments 1995. NOAA Tech. Memo. NMFS-AFSC-57. National Marine Fisheries Service. 93p.
- Olesiuk, P., pers. comm., as cited in National Marine Fisheries Service. 1995. Proposed change in listing status of Steller sea lions under the Endangered Species Act. *Federal Register* 60(192):51968-51978.

Together, funding for Steller sea lion research by all sources was about \$2 million in 1997. With regard to population monitoring, the Service and the State of Alaska have undertaken studies to assess and monitor the condition, productivity, and survivorship of sea lions at selected rookeries, and to coordinate a series of biannual statewide or rangewide surveys. The last rangewide survey was conducted in 1994 and the last statewide survey in Alaska was conducted in 1996. A summary of counts of adult and juvenile sea lions at key trend sites in Alaska that have been monitored since the 1970s is shown in Table 5. In 1998 the Service plans to conduct another rangewide survey in cooperation with scientists in Russia and Canada.

Given the suspected role of prey availability in the decline, particular emphasis has been placed on stud-

ies to better define feeding patterns and food preferences, and to look for signs of nutritional stress. For example, the Service has undertaken studies of declining sea lion colonies in the Aleutian Islands and western Gulf of Alaska to identify prey preferences by collecting and analyzing scats and comparing fatty acids in prey species and sea lion blubber. It also has been monitoring the condition of pups using weights and blood parameters, and tracking individual animals by satellite telemetry to identify at-sea foraging areas.

The Alaska Department of Fish and Game has undertaken similar studies in southeastern Alaska where rookeries and haul-out sites have been stable to provide a basis for comparing patterns between areas that are stable or increasing and areas that are declining. The Marine Mammal Consortium has undertaken

research on captive as well as wild sea lions to assess energetic requirements, identify the effects of restrictions in the amounts and types of food on blood chemistry and body condition, compare scat remains from captive sea lions with known diets with those collected in the wild, and develop new telemetry techniques to monitor feeding activity based on changes in stomach temperature. Many other studies also have been undertaken by these groups over the past several years.

To ensure that research provides the best possible basis for management decisions, the Steller Sea Lion Recovery Team recommended early in 1995 that a series of workshops be held to identify and rank future research priorities in four study areas: behavior patterns of sea lions at haul-out sites and rookeries, satellite telemetry, physiology, and food and feeding ecology. The purpose of the recommended workshops was to review ongoing and past work to help plan and prioritize future research activities and provide a basis for updating the Steller Sea Lion Recovery Plan (see below). Among other things, the workshops were intended to evaluate research hypotheses and methodologies, evaluate whether ongoing projects are likely to address proposed hypotheses, evaluate how ongoing studies complement one another, identify needs for coordination among related studies, and make recommendations for continuing, modifying, or deleting specific studies.

Although the team recommended that the workshops take place in 1996, lack of money and a vacancy in the Service's Steller sea lion coordinator position delayed things until late in 1997 when the two workshops were held. The first was a behavior workshop held on 5-7 December, and the second, a workshop on telemetry studies, was held on 8-10 December. During the workshops, scientists presented study results and plans to a panel composed of members of the Steller Sea Lion Recovery Team and outside experts not involved in Steller sea lion research. The format was designed to provide an independent perspective on program priorities and needs.

At the end of 1997 findings from the two workshops were being prepared for submission to the National Marine Fisheries Service early in 1998. The results are expected to be factored into research plans

for the 1998 field season. Plans for the remaining two workshops on physiology studies and food and feeding ecology studies are expected to be held in the fall of 1998.

Steller Sea Lion Stock Assessments

In response to provisions added to the Marine Mammal Protection Act in 1994 to address interactions between marine mammals and commercial fisheries (see Chapter III), the National Marine Fisheries Service completed stock assessments for the eastern and western Steller sea lion stocks in 1995. Among other things, the new provisions require that stock assessment reports, which are required for every marine mammal stock in U.S. waters, estimate the minimum stock abundance, calculate a potential biological removal level that could be taken annually from a stock (not including natural mortality) and still allow it to increase towards its optimum sustainable population level, and estimate the current level of human-caused mortality and serious injury.

To calculate the potential biological removal level, the Service multiplies the minimum population estimate by the maximum theoretical net productivity rate for the species and a safety factor. For populations that are declining, such as Steller sea lions, the Commission expressed concern about using the maximum theoretical net productivity rate and instead recommended that the current net productivity rates be used. However, the Service has not adopted this recommendation.

The 1995 stock assessment for the eastern Steller sea lion stock concluded that the minimum estimate of stock size was 23,900 sea lions, the potential biological removal level was 1,059 animals per year, and the recent level of human-caused mortality was eight sea lions per year (including four killed in commercial fisheries and four by Native subsistence hunters). The assessment report for the western stock stated that a minimum estimate of stock size for western Alaska was 42,536, the potential biological removal level was 766 animals per year, and the number of human-related deaths per year was 555 animals, including 41 sea lion deaths resulting from commercial fishing operations and 514 animals taken in Native subsistence harvests.

Table 5. Counts of adult and juvenile Steller sea lions at rookery and haul-out trend sites in seven subareas of Alaska during June and July aerial surveys, 1976-1997

Area	1976	1979	1985	1989	1990	1992	1994	1996	1997	Percent Change since First Count
Eastern Stock										
Southeast Alaska	—	6,376	—	8,471	7,629	7,558	8,826	8,281	—	+30%
Western Stock										
Gulf of Alaska										
Eastern	7,035	—	—	7,241	5,444	7,558	3,369	2,131	—	-70%
Central	24,678	—	19,022	8,552	7,050	6,273	4,520	3,913	3,352	-86%
Western	8,311	—	6,275	3,908	3,915	3,734	3,982	3,738	3,633	-56%
Aleutian Islands										
Eastern	19,796	—	7,505	3,032	3,801	4,839	4,421	4,714	—	-76%
Central	—	36,232	23,042	7,572	7,988	6,399	5,790	5,428	—	-85%
Western	—	14,001	—	—	2,327	2,869	2,037	2,189	—	-84%

Sources:

Sease, J.L., J.P. Lewis, D.C. McAllister, R.L. Merrick, and S.M. Mellow. 1993. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June and July 1992. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-17. 57p.

Strick, J.M., L.W. Fritz, and J.P. Lewis. 1997. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June 1994. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-71. 55p.

National Marine Fisheries Service unpublished data.

During 1997 the Service drafted revised stock assessments that were expected to be circulated for agency and public review early in 1998. At the end of 1997, it was the Commission's understanding that the draft revised assessment for the western stock of Steller sea lions had not incorporated the results of stock surveys since 1994. As a result, it understood that the estimated stock size and potential biological removal levels in the revised assessment for the western stock were unchanged from those in the 1995 assessment despite new information indicating that the stock size had decreased significantly since 1994.

Workshop to Assess Steller Sea Lion Management Measures

As part of its proposal to change the status of Steller sea lions under the Endangered Species Act, the National Marine Fisheries Service requested comments on the adequacy of existing regulations to protect Steller sea lions. In this regard, the Commission's 11 January 1996 comments noted that, while it was not clear how effective fishing regulations have been in protecting sea lions, the continuing decline of the western stock indicates that they have not been adequate to halt the decline. The Commission there-

fore concluded that the most effective way to develop and evaluate appropriate fishery management measures may be through an experimental approach whereby different regulations or management measures are applied to different haul-out sites and feeding areas. To consider optional approaches in this regard, the Commission recommended that the Service convene a panel of independent experts to evaluate and make recommendations on the full range of fishery management practices that may be useful for reversing the decline of Steller sea lions.

In April 1996 the Service convened a meeting to plan such a workshop, and on 6-7 May 1997 it convened a panel of independent marine scientists and resource managers to develop an experimental design for evaluating the effectiveness of existing management measures to protect sea lions and their feeding areas. While the primary objective of the workshop was to consider experiments to test the efficacy of exclusion zones around major rookeries and haul-out and feeding areas, other experiments were also to be considered, such as tests of the effect of fisheries on prey availability. At the end of 1997 the Service was expected to release the panel's findings early in 1998.

Updating the Steller Sea Lion Recovery Plan

In 1988 the Marine Mammal Commission published a series of species accounts with research and management recommendations for 10 marine mammal species in Alaska, including Steller sea lions (See Lentfer 1988 in Appendix B). The purpose of the accounts was to summarize species-specific information that the National Marine Fisheries Service and the Fish and Wildlife Service could use as a basis for developing research and management plans on individual species in Alaska. Since then, the two agencies have developed conservation plans or recovery plans for about one-half of those species. Among the plans that have been developed is a recovery plan for Steller sea lions drafted by the Steller Sea Lion Recovery Team and adopted by the National Marine Fisheries Service in 1991.

During the Steller Sea Lion Recovery Team's meeting on 3-4 April 1997, the team concluded that the recovery plan should be updated to reflect new information and priorities that have been developed

since the initial plan was drafted. During the Marine Mammal Commission's annual meeting on 18-20 November 1997, representatives of the Service expressed their support for the team's efforts to update the plan. As noted above, the series of research workshops recommended by the recovery team are expected to provide an important basis for updating the plan. The recovery team expects to begin drafting a revised plan soon after that series of workshops is completed.

As a related matter, given the large amount of new information on Steller sea lions developed soon after the Marine Mammal Commission published its series of Alaska species accounts in 1988, the Commission in 1991 contracted for an update of its account for Steller sea lions. The update was not completed and a new contractor, working with the original contractor, expects to have the revised species account ready for review early in 1998, and publication is expected later that year. Along with the results of the series of workshops discussed above, the report should form a solid basis for revising the recovery plan.

As of the end of 1997 it appeared likely that an update of the recovery plan would be done late in 1998 or early in 1999.

Steller Sea Lion Subsistence Harvests

Steller sea lions are hunted by Alaska Natives in several coastal villages for subsistence purposes. Prior to the early 1990s little information was available on the numbers of sea lions taken by Alaska Natives. Therefore, to develop information on the subsistence hunt of Steller sea lions, as well as harbor seals, the National Marine Fisheries Service contracted with the Alaska Department of Fish and Game to conduct interviews with Native hunters in more than 60 coastal villages throughout the species' range. The interviews have been conducted annually since 1992.

The survey results suggest that the subsistence take of Steller sea lions has decreased steadily in recent years from an estimated 549 animals in 1992 to 339 in 1995. More than 90 percent of this take has occurred in areas occupied by the western stock, with Native hunters on the Pribilof Islands taking between 20 and 55 percent of total statewide catch. Interview

results regarding hunting effort in 1996 again indicated that few animals are taken from the eastern stock. The estimated subsistence harvest for all areas of Alaska except the Pribilof Islands was 140 sea lions. For the Pribilof Islands, however, information suggests that take estimates based on the interview data significantly underestimate the number killed, and thus, the statewide estimate of subsistence take for 1996 remains uncertain. At the end of 1997 results of harvest interviews in 1997 were not yet available.

Native subsistence harvests from the eastern stock of Steller sea lions are far below the potential biological removal level calculated by the National Marine Fisheries Service. However, harvest estimates from western Alaska are close to the calculated potential biological removal level for the western stock and hunting pressure has been focused at a relatively few haul-out sites. Also, there is concern about takes from the western stock because it is heavily impacted by factors other than direct human-caused mortality.

Recognizing the interest and role of Alaska Native hunters in conserving Steller sea lions, the Service has worked closely with them on sea lion conservation efforts. Among other things, Service officials met with Native sea lion hunters on the Pribilof Islands in August 1996 to discuss hunting practices that would minimize adverse impacts on sea lions. During the Marine Mammal Commission's annual meeting on 18-20 November 1997, it was noted that guidance on appropriate sea lion hunting practices had been developed by hunters on the Pribilof Islands, but the suggested practices had not yet been fully implemented. In May 1997 the Service also met with Native hunters to discuss development of a co-management agreement for Steller sea lions.

As noted in Chapter V, an umbrella agreement was signed in 1997 for developing a series of co-management agreements between the Service and various Native groups on the conservation of several species of marine mammals in Alaska. Although discussions were initiated on a co-management agreement and a Native commission on Steller sea lions in 1996, little progress was made in 1997 to bring these efforts to fruition. During the Commission's annual meeting in November 1997, the Service indicated that further meetings with Native representatives were planned.

Northern Fur Seal (*Callorhinus ursinus*)

Northern fur seals occur in coastal waters of the North Pacific Ocean from southern California to Japan and in pelagic waters from about 35°N latitude to the central Bering Sea (Fig. 6). About three-fourths of all northern fur seals breed and pup on St. George Island and St. Paul Island in Alaska's Pribilof Islands. Elsewhere, northern fur seals breed and pup in Russia on the Robben, Kuril, and Commander Islands. Small rookeries are also found on Bogoslof Island in the central Aleutian Islands and San Miguel Island off southern California. When not on these islands, northern fur seals usually are found at sea feeding. Many pups remain at sea for up to 22 months once they leave their natal rookery. Fur seals display a high degree of natal site fidelity, usually returning to their colony of birth to breed and molt.

Northern fur seals were harvested commercially for their pelts beginning in the late 1700s. By the 1800s excessive pelagic harvests of males and females of all ages threatened the species' economic and biological viability. As a result, the principal harvesting nations — Canada, Japan, Russia, and the United States — signed the Fur Seal Treaty of 1911. The treaty banned pelagic harvests in lieu of arrangements to share pelts from a managed onshore harvest of sub-adult male seals taken on U.S. and Russian rookeries. By limiting the harvest to sub-adult males, fur seal numbers were able to increase substantially over the next 30 years.

The treaty lapsed during World War II, and by the early 1950s the Pribilof Islands fur seal population had grown to about two million animals — a number thought to be at or near its pre-exploitation size. Beginning in 1956 some females as well as juvenile males were taken. This action was taken under a wildlife management theory prevailing at the time which predicted that, after an initial decline in fur seal numbers, pup production and survival would increase as the population attempted to compensate for animals removed by the harvest. This harvest strategy was continued under the Interim Convention for the Conservation of North Pacific Fur Seals, signed in 1957 by the four signatories to the former treaty.



MARINE MAMMAL RESEARCH

A Newsletter of The North Pacific Universities Marine Mammal Research Consortium

No. 3, 1997

Steller Winters

When a 16-oz can of pork and beans is kept cold enough, long enough, it explodes with a noise like a pistol-shot, scattering little bean-pellets everywhere, and leaving behind shrapnel-like fragments of torn metal. That discovery was but one of the pieces of scientific data brought back by Consortium researcher Boyd Porter. Porter spent three of 1996's coldest months camped out in below freezing temperatures on a small chunk of rock with the disingenuous name of Timbered Island, located a few kilometers off the coast of southeast Alaska.

Porter's presence on the island was deliberate. He was there to observe the wintertime behaviour of a herd of adult and juvenile Steller sea lions. His discovery of the explosive properties of 16 oz tins, however, was entirely inadvertent. "I couldn't get the propane heater going," explains Porter. "I'd get it lit and think – thank God, now I can go to sleep – and then I'd watch the flame sputter out again."

The heater, the tin cans, the 8x10 cabin in which Porter slept, even Porter himself had all been transported to the remote site via ship and helicopter. No plans had been made for a re-supply drop. When he put in a radio call the next day for a replacement part for the heater, his supply team could only promise to do their best. Six weeks passed before he got the part, air-dropped in a Rubbermaid container.

Despite the difficulties Porter – a burly 6 ft tall Alaskan – doesn't like to dwell too much on the discomforts of winter field work. "No one would ever want to do a winter field study again if I told what it was really like," he says. No one had ever done one before him for the obvious reason that spending extended time on the exposed Alaska coastline when the storms of winter come whipping unchecked across the Pacific can be an uncomfortable, even dangerous pastime.

And a vitally important one.

The Steller sea lion of Alaska has been in steep decline for nearly two decades. Over 75% of the



Steller sea lions give birth to a single pup in June. Some pups will remain with their mothers for up to three years.

animals have disappeared since 1980. "It's thought by many researchers that understanding juveniles is critical to unraveling the decline," says Porter. Population models have suggested that a poor survival rate among juvenile Stellers may be what is driving the population decline. The period during which the young Stellers switch from a diet of mother's milk to fish is thought to be especially critical. But until Porter began his study, no one had ever gone out to observe Stellers during the coldest, darkest half of the year when these events take place. "As far as we knew the animals were simply dying off during the winter," says Porter. "That, along with gathering natural history information about the winter ecology was the reason we began this whole study."



An aborted fetus discovered in January at a winter haulout site.

During his months on Timbered Island, Porter didn't discover any mysterious mass mortality of juvenile Stellers, but he did observe a high incidence of aborted fetuses. "The high abortion rate leads you to wonder whether the problem with Stellers is not that they are dying young, but that they are not being born in the first place," says Porter.

Reproductive failure aside, Porter has also uncovered a critical fact about winter behavior patterns that few Steller researchers had suspected: juvenile Steller herds are extremely skittish in winter. In the summer, Steller sea lion herds are generally quite tolerant of human disturbance, the result in Porter's view of the presence of a relatively high number of mature animals. On the winter haulouts, however, there is a much higher proportion of juvenile animals.

Porter observed one site that was home to approximately 60 adult females and 150 juveniles. Almost anything, says Porter, was enough to scare the herd. "Even an eagle flying overhead would cause the juveniles to panic and stampede towards the water. The adult females don't know what's going on and they don't wait to find out. In an instant, one massive stampede is underway, leaving the haulout bare."

Unlike summer animals, the winter animals will often not return to the haulout for days. Porter had come equipped with a number of ways of marking the Stellers, including paint pellets launched by a heavy-duty slingshot. But the skittishness of his subjects forced him to reconsider, for fear of driving off the animals for good. Fortunately, the Alaska Department of Fish and Game had some years earlier branded 800 pups on rookeries (breeding sites) some 200 kilometers to the south. As many of

these animals showed up at Porter's site he was able to use the markings to identify the animals in his study of such basic biology as wintertime activity budgets and nursing patterns.

Porter's original intention had been to compare this data — collected in Alaska's southeast where Stellers are thriving — with similar information collected at sites at Cape St. Elias and Marmot Island in the Gulf of Alaska, where Stellers have declined. It was hoped that comparing the two populations would yield some clues as to what is driving the Steller decline. Unfortunately, attempts to capture Stellers at the Marmot Island field site by an independent group of researchers changed those plans. The process of attaching satellite packs so spooked the young Stellers that they never returned in force to Porter's research site.

All is not lost, however. In January, 1997, a team of Consortium researchers returned to Marmot Island in the area of the decline to gather wintertime data on juvenile Stellers. "My first job [after they get back]," says Porter, "will be to take the data they gathered using my protocols and do the comparison and see if I can figure out what's driving the decline."

Porter's groundbreaking work on winter Steller ecology will also help establish a solid baseline for all future work "A lot of graduate work," says Porter, "is kind of like an exercise to prove that you can do science. It's kind of nice to know that this," he says pointing to the stacks of collected data on his desk, "will be used in a lot of work to come."

Boyd Porter: tracking individual Steller sea lions from dawn to dusk at one of Timbered Island's winter haulout sites.



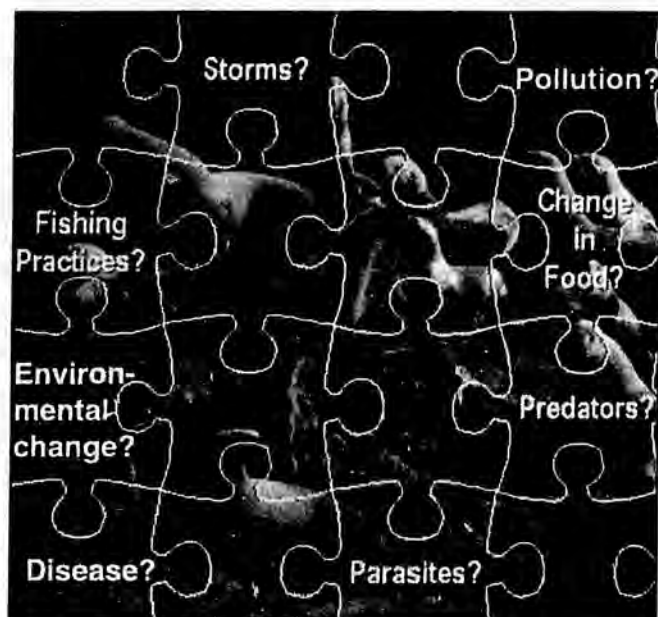
Ecosystem Puzzles

One of these things is not like the other. This old Sesame Street strategy forms the basis of a surprising amount of scientific research, including a study recently completed by University of Washington researcher Dr. Michio Shima. Shima compared the Gulf of Alaska with three similar ecosystems – the Barents Sea, the California Current, and the Benguela Current off the southwest coast of Africa – to see if it would help shed some light on the mysterious decline of Alaska's Steller sea lion population. Seals and sea lions are currently abundant in all of these ecosystems, except in the Gulf of Alaska. "I wanted to figure out what made the Gulf of Alaska unique in terms of some factor that could be causing the decline of Steller sea lions."

The presence of a large commercial trawl fishery was an obvious suspect, if only because the onset of the Steller population's decline coincides almost exactly with the expansion of the shore-based trawl fishery in the Alaskan Gulf. Shima's research, however, found that a large commercial fishing fleet is something all four ecosystems share. "If anything," says Shima "the rates of exploitation in the Gulf of Alaska are actually on the lower end of the scale in comparison with the Barents Sea and Benguela Current." She also found that direct interactions in the Gulf between Stellers and fishing boats were negligible in comparison with the other ecosystems.

So Shima turned her attention to environmental variables. A variety of evidence, including air and water temperature, atmospheric dust levels, CO₂ concentrations and ice cover suggests that the Gulf of Alaska and indeed the whole North Pacific experienced a stepwise environmental shift sometime in the late 70s. Perhaps most significantly for Stellers, arrowtooth flounder populations have increased dramatically since that time, even as the Steller sea lion population has declined. Arrowtooth flounder feed on pollock and capelin – known prey items for Stellers – so it's possible that the flounder are out-competing the Stellers for food. However, Shima's modelling work has shown that the abundance of pollock is sufficient to feed both Steller sea lion and arrowtooth flounder populations.

In any case, shifting environmental patterns are not unique to the Gulf. They too, are another thing all four ecosystems share. "Looking at environmental patterns and trends, all of them have gone through



Why Steller sea lions are disappearing throughout most of Alaska remains a puzzle.

changes between warm water and cold water regimes."

In fact, the only really significant difference Shima discovered was the undifferentiated nature of fish species in the Gulf. "I did a comparison of total biomass in the Gulf, and it's certainly not lacking in biomass." What is lacking is variety. "There isn't the same kind of small prey switching in the Gulf as there is elsewhere," says Shima. In the Barents Sea for example, there is a pretty regular variation over time between cod, herring and capelin stocks. The Barents Sea harp seal population switches opportunistically between these prey species, taking whatever is most readily available. "You don't see that with Stellers," says Shima. "Their dominant prey resource has remained pollock over the past two decades."

Preliminary research results from Consortium researcher Dr. David Rosen suggest that an all-pollock diet may not be especially healthy for Stellers. However, pollock have never constituted the entire Steller diet, and Shima's modelling results indicate that the abundance of pollock is sufficient. What is less clear is whether the decline of Steller sea lions could be related to small scale changes in the distribution of pollock. Now a post-doctoral fellow at the University of Washington, Shima is continuing her research into possible mechanisms for these changes, still looking for that one thing that is not like the other.

Northern Fur Seals

For over a century the northern fur seal was a veritable gold mine, earning sealers thousand of dollars annually until the stocks were critically depleted. Today, seventy years after the unregulated hunt ended, the fur seal is once again yielding up wealth, this time in the form of scientific information. Like the Steller sea lion, the fur seal has been hit by a mysterious population decline. Fur seal populations have been halved since the mid 1950s. Unlike the non-commercial Steller, however, the commercially valuable fur seal has been studied for over a century.

"There's just a wealth of data on this animal," says Consortium Director Dr. Andrew Trites. In revisiting this data to see if it could shed any light on the Steller decline, Trites uncovered a relationship between seal body length and the total seal population that seems to indicate that the current fur seal population may be the maximum sustainable in today's Bering Sea ecosystem. "Today's population appears to be at carrying capacity, which is half of what it was 40 to 50 years ago," says Trites.

Before any solid conclusion can be drawn, however, some gaps in the data need to be filled in. Trites hopes to use an innovative technique that involves examining the teeth taken by fisheries officials from fur seals over the past century. "Fur seal teeth contain a series of annual growth rings, much like the rings of a tree," says Trites. "Wider rings mark years of high growth and good feeding conditions. Comparing the growth rates from one year to the next may allow us to assess annual changes in the productivity of the North Pacific Ocean, as well as determine if an ecosystem shift occurred in the mid 1970s." Such a gold mine of information locked within each tooth contains a potentially important story about what has happened to the northern fur seals and the other species that share the North Pacific.

What's for Dinner?

As part of its ongoing work to determine the cause of the Steller sea lion decline, Consortium researchers from the University of Alaska will try this summer to assess the types and relative abundance of fish available to sea lions at Forester Island in Southeast Alaska, where Stellers are thriving. Other researchers from the University of British Columbia will track sea lions at sea using satellites to find out where and when they feed. They will also determine what the sea lions chose to



Most of the world's population of northern fur seals are born in July on the Pribilof Islands in the Bering Sea.

eat by identifying the bones of fish found in the sea lion scats (feces) left on the rocks. The data from this survey will be compared to data from a similar study conducted in the Gulf of Alaska where Stellers are declining. These studies provide a critical opportunity to test the hypothesis that prey availability is not adequate to support sea lions throughout most of their range.

Other Studies

Consortium researchers continue to study the nutritional needs of Steller sea lions housed at the Vancouver Aquarium. They will soon begin constructing a bioenergetics model to predict the food requirements for sea lions in the North Pacific, and plan to use an ecosystem model to determine whether the ecosystem shifted to lower levels of carrying capacity in the mid 1970s. Plans are also underway to study the role that disease and reproductive failure may be playing in the decline of Stellers. Results of these and other studies carried out by researchers at Oregon State University, and the Universities of Alaska, British Columbia and Washington will be highlighted in future newsletters.

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The North Pacific Universities
Marine Mammal Research Consortium
The University of British Columbia
Hut B-3, Room 18
6248 BioSciences Road
Vancouver, BC V6T 1Z4 Canada
Tel: (604) 822-8181
Fax: (604) 822-8180
e-mail: consortium@zoology.ubc.ca



MARINE MAMMAL RESEARCH

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Sea Lion Pills

The island of Yunalaska rises out of the Bering Sea about mid-way along the Aleutian archipelago, smack in the middle of the region where Steller sea lions first began disappearing over 15 years ago. On June 5, 1996, the research vessel Provider was nosing its way slowly in toward Yunalaska's sheer basalt cliffs, looking for a place to anchor. Consortium researcher Russ Andrews – aboard a second research vessel in Alaska's southeast – later spoke with eyewitnesses about what happened next.

"They were only about 100 feet from the rocks," says Andrews, "when the skipper tried throwing the boat into reverse. Nothing happened." Reverse was jammed, or broken. There was no room to turn around. Ocean swells soon carried the little boat to the cliff face, and slammed it against the rocks with a crunch that sounded the death knell for the 1996 field season.

The National Marine Fisheries Service (NMFS) had chartered the Provider so that Andrews and other researchers could further investigate the mysterious decline in Steller sea lion numbers that has seen two-thirds of the Alaskan population disappear since 1980. The Alaska Department of Fish and Game had chartered a second vessel so that identical studies could be conducted at the same time in Southeast Alaska, where Stellers are thriving. In preparation for the voyage, Andrews had packed up several gallons of marine epoxy, and a small electronics shop worth of telemetry gear. Thus armed, he planned to take a shot at a question that scientists, wildlife managers, and fishermen had been asking since the decline began: namely, is it food?

The idea that Stellers weren't getting enough to eat was one of the first hypotheses put forward by scientists after the Steller decline was discovered in the early 80s. A symposium entitled *Is it Food?*, was held at the University of Alaska in 1991. Some researchers believed that the expansion of the Bering sea trawler fleet might have reduced available fish stocks. Others felt a longer term shift in the ecosystem might be responsible.



Steller sea lions: where do they feed and are they getting enough to eat? To answer these questions some sea lions are carrying satellite tracking tags and stomach temperature pills.

The most direct way of testing this hypothesis was to compare the foraging patterns of animals from the declining populations in the Aleutians and Gulf of Alaska with those in the flourishing populations in the Southeast. Unfortunately for researchers, Stellers invariably forage underneath many feet of cold, dark ocean. At the time they were declared threatened, no one was sure how to monitor exactly where and when they were feeding. Enter Russ Andrews.

While working on his Ph.D. at the University of British Columbia, Andrews developed a telemetry system for elephant seals that, among other data, was capable of recording stomach temperature. It had immediate applications for research with Stellers. "When I first got into this stomach temperature stuff," says Andrews, "it was mostly for getting a look at what is the body temperature of elephant seals out at sea. Then as kind of a byproduct of that I thought, hold on, we can use this to look at foraging



Female number 122 (sprayed on with hair dye) with a foraging data logger.

as well. So when the sea lion crisis came along, to me it was the perfect tool to use to try to answer the question, Is there something different between the stable and declining populations in terms of food availability?"

Answering that question, Andrews explains, really means coming up with answers to a number of smaller questions. "You need to know whether animals in the declining population have to spend more time getting their food; if they have to work harder; if they're getting less food. You need to know when are they getting food and how much food they are getting. This was the perfect tool to look at those things."

A tool that could provide data on where and when Stellers forage would be extremely valuable to wildlife managers faced with identifying critical habitat, a task that became mandatory after Stellers were declared threatened in 1990. It would also be useful to scientists trying to develop more accurate models of Steller sea lion energetics.

Even the perfect tool, however, requires a little R & D – Research and Development. In fact, Andrews spent many months crouched over circuit boards improving his existing telemetry system and adapting it for use with Steller sea lions. The result was an innovative two-part telemetry system. One part, called a foraging data logger (FDL), is designed to be epoxied onto the fur on the sea lion's back. It samples and stores data such as dive depth and water temperature, time, body temperature and swim velocity. When the sea lion is on the surface, the FDL also links up with a satellite to determine the animal's position. Finally, the FDL records a signal coming from the second part of the telemetry system, a twinkie-sized titanium cylinder called a stomach pill.

The sea lion swallows this component whole. The pill then gives off a signal with a frequency that varies with the temperature of the animal's stomach. Knowing the stomach temperature, it becomes possible to determine not only when but also how much a sea lion has been eating.

Ordinarily, the temperature of a warm-blooded Steller's stomach is the same as the rest of the animal's core. However, when the sea lion ingests one or more fish, the stomach temperature drops rapidly until it is fairly close to that of the cold-blooded prey. It then slowly rises again as the ingested prey warms up, eventually returning to the original core temperature. Thus, a large sudden drop in stomach temperature indicates a feeding event. The magnitude and duration of this drop in temperature is proportional to the amount of food ingested.

To calibrate the device, Andrews has been working with the captive Stellers at the Vancouver Aquarium. In a series of trials, animals harnessed with the telemetry system are fed known amounts of fish, and their stomach temperature curves recorded (see photo on opposite page). When the trials are completed in 1997, it should be possible to determine exactly how much a given Steller has eaten, just by looking at the stomach temperature graph.

Even now, field tests of the system have yielded some valuable results. In 1994, Andrews conducted trials on Alaska's Forrester Island with seven 7 mature females. Three of the devices were never recovered, but the remaining four yielded data for foraging trips that lasted from 8.5 to 50 hours. The results were surprising. "Until I did my work," says Andrews, "it was just sort of assumed that the animals were feeding the whole time they were underwater." The results, however, showed that Stellers sometimes search for up to 6 hours before successfully capturing prey.

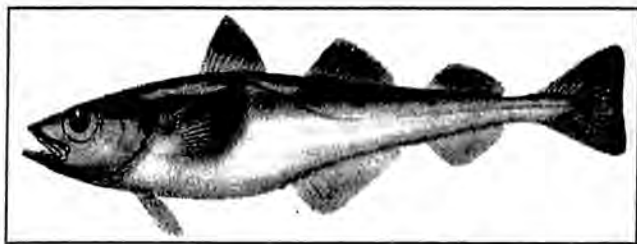
If the behavior of these four animals sets the pattern for the entire population, then many of the previous models on sea lion activity budgets will have to be revisited. More data are needed, however, before a solid conclusion about foraging behavior can be drawn. That's why Russ Andrews will be back out there in June, 1997, hoping that this will be the year that the comparative feeding study can be completed, and that no unforeseen events will ground this year's attempt.

The Problem with Pollock

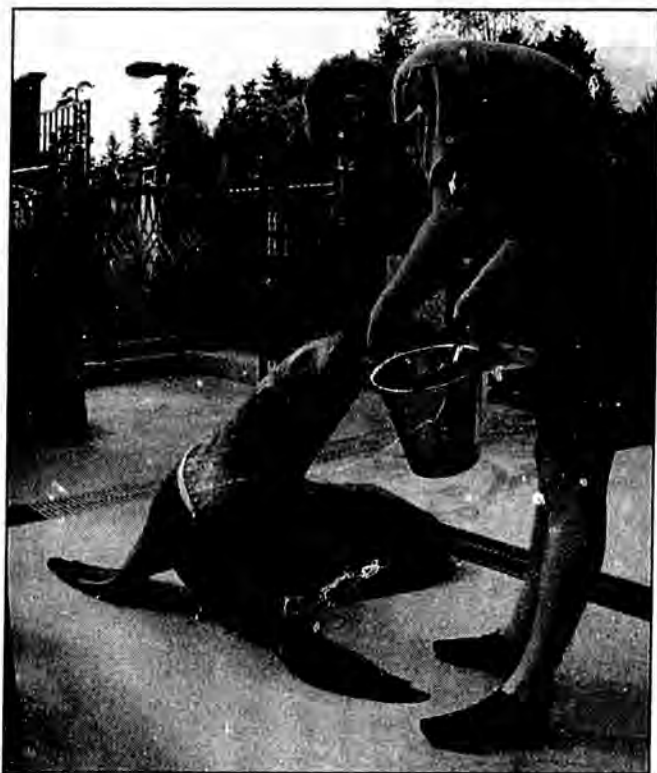
If you're a sea lion, pollock makes a lousy meal. That's suggested by the data from a number of captive feeding trials conducted at the Vancouver Aquarium by Consortium researcher Dr. David Rosen. During one trial, captive sea lions were fed exclusively on pollock, and despite the fact the sea lions were fed essentially ad lib – meaning they could eat as much as they wanted – the Stellers actually lost body mass. "You're talking 16 to 18 kilograms in only two weeks," says Rosen. "That's a major loss of weight for an animal that only weighs about 100 kg."

Rosen was particularly surprised that the sea lions weren't able to compensate in some way for the low energy diet. In a separate trial currently underway, Rosen has found that when Stellers are fed exclusively on squid – another low-energy food – they attempt to compensate by reducing their basal metabolism by as much as 25%. In spite of this, the squid-fed Stellers also lost weight. Trials with pollock haven't yet been completed, but Rosen expects the results to be similar. The ability to slow metabolic rate down, even combined with a limitless supply of fish, does not appear to be enough to keep pollock-fed Stellers healthy.

"When you see a drop in body mass like that," says Rosen, "you know that something serious is happening to their physiology. They're probably doing everything they can to compensate, but they're just unable. So in a wild population, it's hard to imagine any adjustment they could make so that they could survive on a total pollock diet. They just wouldn't be getting enough energy."



Walleye Pollock: *Theragra chalcogrammus*



Woody, one of six young Steller sea lions participating in the dietary studies at the Vancouver Aquarium.

That Stellers fare poorly on pollock lends credence to the "popcorn of the sea" theory put forth some years ago by fisheries consultant Dr. Lee Alverson. A specialist in fisheries management, Alverson hypothesized that the Steller decline was due not so much to a lack of prey, but to the low energy value of that prey. Pollock is now the single largest prey species in the area of decline. The results from the feeding trials suggest that Stellers could be starving in the midst of all this apparent abundance, just like a person that tried to live exclusively on popcorn.

Dr. Rosen has also been working with the captive Stellers on a number of trials designed to investigate the efficiency with which Stellers make use of different prey species. His work has resulted in a report, entitled *Heat Increment of Feeding in Steller Sea Lions*, that shows that Stellers lose out twice by ingesting low energy food like squid and pollock. Firstly, because of the simple fact that they are getting less energy in total, and secondly, because low-energy food has a higher relative cost of digestion. It seems that for sea lions, a healthy life style does not include a low-fat diet.

Harbor Seal Declines

Like Steller sea lions, harbor seals have also declined in most regions of Alaska (as much as 90% in some areas). The only exceptions to these trends are in Southeast Alaska and Bristol Bay.

Genetic research has shown that there are two stocks of Steller sea lions in the North Pacific. One which is threatened (the eastern stock) and one that NMFS is proposing to relist as endangered (the western stock). The line that divides the two stocks is Cape Suckling, near Prince William Sound.

Under the supervision of Consortium director Dr. Andrew Trites, Theresa Burg has completed an analysis of the genetic structure of harbor seals in the North Pacific. Burg extracted mitochondrial and microsatellite DNA from harbor seal blood and tissue samples taken from different areas of Alaska and British Columbia. The differences she found suggest the presence of three separate populations: 1) Japan, Alaska and northern British Columbia, 2) southern British Columbia, and 3) outer coast of Washington, Oregon and California. Burg estimates the harbor seals originally invaded the Pacific by swimming through the Arctic from the Atlantic Ocean 670,000 years ago. She believes that a second invasion occurred 380,000 years ago and that glaciation and reproductive isolation account for the distinctness of the 3 populations.

Genetics has also provided Burg with insights into the limited movement of harbor seals between southern BC and northern BC / Alaska. Her results show an average of only 20 males and one lone female migrate between the two populations every 30 years. It seems that harbor seals just don't like to leave home!

Other Studies

A collaborative project is currently underway with Dr. Lorrie Rea on the physiological effects of decreased food intake. The goal of the study is to figure out what Steller blood test results should look like if sea lions are indeed nutritionally compromised in Alaska. Dr. Rea is a postdoctoral fellow with NMFS. She is measuring the blood metabolite levels, body mass, and blubber thickness of the captive Stellers at the Vancouver Aquarium as they are subject to periods of reduced food intake and fasting.



Pacific harbor seals: three populations of home-bodies.

Amy Hirons at the University of Alaska has been attempting to delineate long-term changes in the diet of Alaskan Steller sea lions by examining the ratios of stable isotopes in whiskers and archived organ tissues. Her results indicate that a large isotopic shift occurred in the North Pacific in the mid 1970s. It appears that sea lions are still feeding at the same trophic level today as in the past, but that a major change has occurred in the phytoplankton or plants that support the sea lion's food web. This supports the hypothesis that an ecosystem regime shift occurred during the 1970s. Reasons for the change and the impact on Steller sea lions are being investigated.

UBC researchers Linda Milette and Boyd Porter have been diligently compiling and crunching data from many months spent observing Steller sea lions in the wild. Their main goal has been to contrast the behaviors and energy budgets of sea lions in summer and winter, between declining and thriving areas of Alaska. Results of these and other studies carried out by researchers at Oregon State University, and the Universities of Alaska, British Columbia and Washington will be highlighted in future newsletters.

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The North Pacific Universities
Marine Mammal Research Consortium
The University of British Columbia
Hut B-3, Room 18
6248 BioSciences Road
Vancouver, BC V6T 1Z4 Canada
Tel: (604) 822-8181
Fax: (604) 822-8180
e-mail: consortium@zoology.ubc.ca



MARINE MAMMAL RESEARCH

A Newsletter of The North Pacific Universities Marine Mammal Research Consortium

No. 1, 1996

A Killer Steller Puzzle

"ALL I HAD WITH ME THE FIRST TIME I FOUND A DEAD KILLER WHALE ON THE BEACH WAS A 4 INCH KNIFE," recounts researcher Kathy Heise, who participated in a year long study of the effects of killer whales on Steller sea lions in Alaska and British Columbia. Capped in a baseball hat to protect her hair, Heise cut into the rotting flesh while her husband, Lance Barrett Lennard, sat retching 50 feet upwind. For Heise, this opportunity to cut into a dead whale was a "rare gift" because of the wealth of information that lay within its stomach and tissues.

Back in the summer of 1992, another dead killer whale was discovered on the shores of Prince William Sound. Inside this whale's stomach, researchers found flipper tags from 14 Steller sea lions swimming in a soup of marine mammal parts. "For one whale to have contained so many tags was puzzling" says Heise. Did all killer whales eat this many sea lions? Could killer whales have caused the decline of Stellers in Alaska, or were they merely a contributing factor that might prevent the depleted sea lion population from recovering?

With these concerns in mind, a collaborative study was initiated by a team of researchers from the University of British Columbia (Lance Barrett-Lennard and Kathy Heise), Fisheries and Oceans Canada (Graeme Ellis), and the North Gulf Oceanic Society (Eva Saulitis and Craig Matkin). The team surveyed mariners for accounts of predatory attacks on Stellers, compiled the available stomach content information, estimated killer whale abundance, and developed mathematical computer models to examine whether killer whale attacks could significantly affect Steller sea lion numbers. Their intriguing findings are contained in a recently released report titled "The impact of killer whale predation on



Dead killer whales, such as this one being cut up by Kathy Heise, provide valuable insights into what killer whales eat.

Steller sea lion populations in British Columbia and Alaska."

The whale cut up by Heise was one of only 22 killer whale carcasses found with stomach contents in the eastern north Pacific since 1973. Results summarized in the team's report show killer whale stomachs contained either fish or marine mammals, but not both, which suggests specialized feeding. Of the 8 animals that had eaten marine mammals, all had consumed harbour seals, 3 had also eaten porpoises and whales, while 2 had birds and sea lions (including the Steller tags), and one was also digesting an elephant seal.

That some killer whales eat marine mammals, while others dine only on fish, agrees with what scientists have learned about killer whales in the North Pacific. In fact, based on differences in diet, social structure, fin shape, and acoustic behaviour, researchers have split the killer whales of British



Flipper tags from 14 Steller sea lions found in the stomach of a dead killer whale that washed ashore in Prince William Sound in 1992.

Columbia, southeast Alaska and Prince William Sound into two distinct populations: fish-eating residents and mammal-eating transients. Transients are typically seen alone or in small groups of 2 to 10 individuals, and will often travel and hunt silently near shore. Residents, on the other hand, are found in larger groups, spend more time in open water, use echolocation frequently, and do not exchange individuals with other resident groups.

An additional group of whales was recently identified and tentatively called offshores. They have been observed feeding on fish, and have usually been sighted well off the mainland coast near the edge of the continental shelf. Offshores are generally found in large, vocally active groups of 30 to 60 individuals, and have not been seen associating with either resident or transient whales. Little is known about the diets of these offshore whales.

Transients then, are the only kind of killer whales known to feed on Steller sea lions. Using published and unpublished collections of killer whale identification photographs held by the North Gulf Oceanic Society (Homer, Alaska), Fisheries and Oceans Canada (Nanaimo, B.C.), and the US National Marine Fisheries Service (Seattle WA), the research team identified a total of 170 transient whales between northern Washington and southeast Alaska. A further 88 were identified in western Alaska, for a total of 258. This compares to an estimated 200 offshore and 364 resident killer whales identified in British Columbia and southeast Alaska.

To find out if the one transient killer whale with so many sea lion flipper tags in its stomach was the

norm or an exception, the research team distributed questionnaires to mariners along the North Pacific coast asking if anyone had witnessed interactions between killer whales and Steller sea lions. Returns from 126 mariners reported 492 incidences, of which 32 (6.5%) resulted in definite kills. Attacks on sea lion pups were witnessed rarely, although killer whales often were reported near sea lion rookeries.

The research team took the results from the questionnaire, stomach analysis and whale census, and used them to develop a mathematical model of the effects of killer whale predation on sea lion populations. The model indicates that killer whale predation may account for a significant portion of the total annual mortality of sea lions in Alaska and British Columbia. When sea lion populations exceed 100,000, the effects of killer whale predation on sea lion dynamics appears minimal. However, at levels of 50,000 sea lions or fewer, the effects are more significant, and may even be sufficient to drive a population decline.

"Killer whales did not cause the sea lion decline" notes Heise, but adds that "they may now be a significant contributing factor." Indeed, the mathematical model suggests that as many as 18% of the sea lions that die each year in Alaska are taken by killer whales. What is killing the other 82% of the missing Steller sea lions is anybody's guess at this time, and the subject of much debate and considerable research.



Researchers are able to identify individual whales from photographs of their dorsal fins and saddle patches.

Steller Sea Lions: ENDANGERED?

AS RECENTLY AS 1980, THE EXPOSED ROCKS AND ISLANDS ALONG THE PACIFIC RIM, FROM CALIFORNIA TO JAPAN, WERE HOME TO OVER 300,000 STELLER SEA LIONS. Since then, the population has declined to fewer than 100,000. No one knows why. Only in Oregon, British Columbia and southeast Alaska have Steller sea lion numbers remained healthy.

As a result of the overall population decline, Steller sea lions were declared a threatened species in their U.S. range in 1990 under the Endangered Species Act. The National Marine Fisheries Service (NMFS) is now proposing to uplist the sea lions that breed along the Kenai Peninsula and Aleutian Islands from *threatened* to *endangered*. The notification published in the U.S. Federal Register on October 4, 1995 proposes that the species be relisted as two distinct populations, with those east of Prince William Sound (144 °W) maintaining a *threatened* listing, while those to the west are relisted as *endangered*.

Dr. Andrew Trites and Dr. Peter Larkin from the University of British Columbia recently reviewed the proposal to reclassify Steller sea lions. They support the proposal to separate the population into two distinct segments. However, they disagree with the proposed reclassifications. Based on the available scientific information, Trites and Larkin believe that the western stock should remain listed as threatened and should not be changed to endangered at this time. The increasing eastern stock should be delisted.

There are 38 major rookeries and over 250 haulouts in Alaska. Most are on remote and exposed rocks and islands. The animals at each rookery site can be thought of as discrete populations. Tagging and branding studies show that the majority of marked pups return to their rookeries of birth as breeding adults. Stronger evidence for the discreteness of rookery populations also comes from genetic samples, and indicates a break in the breeding distribution along the Yakutat region of Alaska.

Except at the periphery of its range in California, all of the eastern populations are stable or increasing, and all appear to be healthy and larger



than in the past few decades. Trites and Larkin dispute the four reasons cited by NMFS for maintaining the healthy eastern stock as threatened, noting that there is "insufficient justification". "If this population is threatened then so are almost all other free ranging, wild populations" say the authors. "They are not threatened and should therefore be delisted".

The NMFS proposal to reclassify the western stock as endangered is based on two key arguments: 1) negative trends in population monitoring data, and 2) extinction predictions from a population viability analysis. Census counts from all regions of the Aleutians and Gulf of Alaska show an overall downward trend. However, the decline appears to have slowed or stopped within 4 of the 7 regions that make up this area. As for the technique used to foretell the demise of Steller sea lions, it is misleading and does not actually assess the viability of the population. In fact, it can only yield one inevitable outcome, extinction, for all populations that experience a period of decline. Trites and Larkin note that "if this type of analysis was extended to humans, then based on recent trends, world population is headed for infinity, and everyone will be unemployed."

Endangered classification should only be applied to those species that are truly at risk of extinction, say the authors. "Such is not the case for Steller sea lions at present."

Fishing Near Rookeries

WHILE THE CAUSE OF THE SEA LION DECLINE IS NOT KNOWN, MANY PEOPLE HAVE BEEN QUICK TO ASSUME THAT FISHERIES MUST BE AT FAULT. Sea lions are believed to currently feed predominately on small to medium sized Walleye pollock, in addition to smaller amounts of Pacific cod, octopus, squid, salmon, Pacific herring, Pacific sand lance, capelin, flatfish, rockfish and Atka mackerel. One way to assess whether fisheries have had an adverse affect is to compare the rate of sea lion population decline with the amounts of fish caught near sea lion breeding areas.

To date, researchers have made at least three attempts to find a connection between fish landings and the sea lion decline. None have been successful. A fourth attempt was made recently by Dr. David Sampson of Oregon State University. In a report entitled 'An analysis of groundfish fishing activities near Steller sea lion rookeries in Alaska', Sampson notes that large winter catches of pollock occurred near sea lion rookeries that suffered large declines in the early 1980s. However, he also reported sharp sea lion declines in other areas in the late 1980s, where no winter catches of pollock occurred. Nor could he relate the declines to the amount of fishing effort, total catches of groundfish, or catches of Pacific cod and Atka mackerel.

It is not clear how to interpret the results of Sampson's study. Does it mean that fisheries removed pollock that were critical to the survival of sea lions during winter? Or, if the catch of pollock was proportional to the abundance of pollock, does it mean that there were many pollock present in relation to other preferred prey? If so, sea lions may not have been eating the best food. Pollock has been termed the junk food of the sea, because it may not be as nutritionally good for sea lions as fattier prey such as herring and mackerel.

Since 1991, new fishing regulations have ensured that no trawling occurs within 10 to 20 nautical miles of sea lion rookeries throughout Alaska; nor may any vessel approach within 3 miles of rookeries west of 150°W (Prince William Sound). "If the winter pollock fishery was connected to the sea lion decline, it should no longer be a factor," says Sampson. "However, the only way to really know would be to conduct an experiment that would exclude fishing in some areas and allow fishing



close to other rookeries, while carefully monitoring the sea lion population."

Other Studies

COMPARATIVE STUDIES ARE BEING CARRIED OUT IN SUMMER AND WINTER IN SOUTHEAST ALASKA (where sea lion populations are healthy) and near Kodiak Island (where sea lions are declining). In addition, studies are continuing on six captive Steller sea lions at the Vancouver Aquarium. Work is focussed on the amount of food the animals need, their ability to digest different prey types, and the development of new techniques to study sea lions in the wild. Analyses are also underway on diet, stress hormones in blood samples, behavioral differences in breeding populations, the development of criteria for classification of endangered species, and the development of mathematical models that explore whether the North Pacific has undergone an ecosystem shift. These and other studies conducted by researchers at Oregon State University and the Universities of Alaska, British Columbia and Washington will be highlighted in future newsletters.

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The North Pacific Universities
Marine Mammal Research Consortium
c/o The Fisheries Centre
The University of British Columbia
Hut B-3, Room 18
6248 BioSciences Road
Vancouver, BC V6T 1Z4 Canada
Tel: (604) 822-8181
Fax: (604) 822-8180

New Blood

Four new Steller Sea Lions pups now make their home at the Vancouver Aquarium and are working with researchers to help figure out why some of their brethren in Alaska are in such dire straits. The two males and two females – named Kodiak, Timber, Hazy and Sitka after haulouts in the Gulf of Alaska – arrived in late June, after being captured off Cape Scott near the northern tip of Vancouver Island. A mere 20 kilograms when they arrived, the pups have since grown to 60 kgs, progressing from formula to liquefied fish to solid herring.

Thanks in part to the knowledge gained by the Aquarium in raising young Stellers, animal health technician Gwyneth Shephard has had no trouble training the new arrivals to take part in several ongoing Consortium experiments designed to understand the energy requirements and the relationship between growth and the different types of fish they eat. Metabolic trials – under the direction of Consortium researcher Dr. David Rosen – are now an expected part of the pups' weekly routine while morphometric measurements – with trainers measuring the pups' length and girth – are conducted twice weekly, again with the pups' full cooperation.

The youngsters have also participated in three different fasting trials, adding greatly to researcher Dr. Lorrie Rea's store of data on Steller blood chemistry and the changes it undergoes in response to food limitation. Such studies have also helped to understand how these creatures adapt their metabolism to periods of low food intake. Active metabolic trials, where the animal's metabolic rate is measured while it exercises in a large swim mill, are planned for the coming months. The pups will also soon experience the chill of their natural seas. A newly installed water-refrigeration unit will enable Consortium scientists to study the effects of cold temperatures on energy demands (the equipment can bring the water temperature down to a frosty 35°F/1.7°C). The pups will also be taking part in a series of new experiments, including tracing hormone levels through saliva samples, the effects of swimming and diving on heart rate, and tests of their visual abilities.

According to Shephard, the pup's sheer trainability should allow Consortium researchers to greatly augment the data obtained working with the previous six Stellers. "We're getting a lot of information that just wasn't possible with the last group," says Shephard. Practice, it seems, makes perfect.



Kodiak, one of 4 new Steller sea lion pups that joined the research team this summer.

Other Studies

A trawl vessel was chartered to assess the types of fish and the relative quantities available to Steller sea lions near their major summer breeding area in Southeast Alaska. Consortium researchers also collected over 400 fecal samples to determine what sea lions were eating, and tracked 10 mature females at sea with satellite tags to determine where and when they were eating. This study will provide valuable insights into the foraging ecology of Steller sea lions and the role that food availability might be playing in the population decline.

Results from the captive feeding studies at the Vancouver Aquarium are being published in the scientific literature. One recently published paper looked at the amount of energy used to digest meals of different sizes (called the heat increment of feeding). Other studies being prepared for publication include the effect of squid consumption on sea lion physiology, the triggers of metabolic depression, and the much-anticipated results of the pollock diet experiment. Results of these and other studies carried out by researchers at Oregon State University, and the Universities of Alaska, British Columbia and Washington will be highlighted in future newsletters.

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The North Pacific Universities
Marine Mammal Research Consortium
The University of British Columbia
Hut B-3, Room 18
6248 BioSciences Road
Vancouver, BC V6T 1Z4 Canada
Tel: (604) 822-8181
Fax: (604) 822-8180
e-mail: consortium@zoology.ubc.ca

Hormonal Surges

Dealing with hormones can be complicated. Just ask any adolescent. It becomes especially tricky when the hormones belong not to people, but to pinnipeds. Just ask Tania Zenteno-Savin. Her Ph.D. thesis – researched and written under the supervision of University of Alaska Fairbanks Professor Michael Castellini – examined the role played by hormones in the physiology of pinnipeds, including Steller sea lions. It was, according to Zenteno-Savin, not at all a simple undertaking. "These little molecules do so much, accomplish so many different things."

For her thesis, Zenteno-Savin focused in on three vasoactive hormones – AVP, ANP, and ANG II – found in the blood plasma. In humans and other mammals, these compounds perform a wide variety of functions: they moderate the resistance of blood vessels, and thus affect heart rate; they participate in the maintenance of water and electrolyte balance; they control to some extent the responses governing hunger and thirst; and they may even play a role in moderating mammalian learning responses. Most intriguing of all, these three hormones might also provide some insight into the ongoing decline of Steller sea lions.

Steller sea lion populations in the Bering Sea and western Gulf of Alaska have been declining since the early 1980s, and according to a 1996 census are now down to under 75,000 animals. A food supply problem is thought by many scientists to lie at the root of the decline, but field observations of Steller rookeries have reported animals that, to human eyes at least, appear completely normal.

In human beings, studies have shown that individuals suffering from eating disorders like anorexia and bulimia have elevated levels of certain blood hormones. Zenteno-Savin felt that Stellers suffering from nutritional stress might well manifest similar changes in their blood hormone levels. To test this hypothesis, she collected and analyzed blood samples from nearly 200 Stellers at various rookeries and haulouts in southeast and northwest Alaska.

Zenteno-Savin also worked with the captive Stellers at the Vancouver Aquarium to determine if either fasting or a food restricted diet had any effect on the animals' blood hormone levels. For the food restricted part of the experiment, 4 juvenile Stellers had their rations cut from 8 kg to 4 kg of herring



per day for a period of 4 weeks. Their blood was sampled before the dieting began and at weekly intervals as it progressed. For the fast, two Stellers were taken off food completely, though water and ice cubes were freely available. Blood samples were taken after 0, 3, 7 and 14 days.

Zenteno-Savin's results were tantalizing, but not completely satisfying. One of the blood hormones, ANG II, did seem to respond to changes in the captive sea lions' diets. ANG II levels more than tripled over the 14 days of fast (of the other two, AVP was unaffected, while ANP seemed to decline, but not significantly). On the surface, this would seem to indicate that blood hormones do provide some gauge of how well a Steller has been eating. Unfortunately, Zenteno-Savin's other work with blood hormone levels in the wild comes in and muddles things up again.

In wild Stellers, Zenteno-Savin found that ANG II levels seem to vary all over the scale, with the levels in animals in the thriving southeast actually coming in higher than in the Aleutians. As well, though ANG II levels certainly rose over the course of the fast, their final value in absolute terms was well within the levels found among wild Stellers.

Zenteno-Savin's gut feeling is that her results hold a valuable clue to the Steller decline, but she also believes it will take a bit more effort to ferret out their full significance. "The hormones are doing so many things that we're just beginning to understand how they function, particularly in marine mammals where there's still so much that we know so little about."

As with so many things in adolescence, it seems, it's going take a few tries before things begin to fall into place.

to see if there were any significant differences in behavior between the two groups that could be correlated to nutritional distress.

Her graduate supervisor, Consortium Director Dr. Andrew Trites, went for the idea, and thus it was that Milette found herself from May to August 1994, sitting 12 hours a day on a rock near a rookery on Sugarloaf Island, noting down every move, every significant shake, snarl and roar of some 30 identifiable Stellers among a herd of more than 100. At the same time, another team of researchers at Lowrie Island in southeast Alaska was noting down the behaviors of a presumably healthy herd of Stellers. In 1995, the two teams, Milette included, came back and did exactly the same thing for another 10 weeks.

The result of these two years of field work was a mountain of data. After two full years of crunching numbers, the results began to sluice out from the data collected, and when they did they were exactly the opposite of what Milette had expected.

"I only found one behavior – the Stellers in the area of decline are more aggressive – that would suggest the animals are nutritionally stressed," says Milette. "Everything else that we found was inconsistent with that prediction."

Milette found that the sea lions on Sugarloaf spent more time nursing their pups and less time at sea searching for food. On the surface, all of these results would seem to indicate that these animals were not experiencing problems obtaining enough to eat, but Milette is nonetheless cautious about jumping to conclusions.

The behavioral differences might merely reflect how far the two sites are from their feeding grounds. Similarly, the fact that pups spend more time

nursing in the area of the decline could indicate that the mothers are actually having a hard time producing milk, and so the pups are sucking away in a vain attempt to get enough sustenance.

There is one result, however, about which Milette is not at all diffident. "The longer perinatal period is the big one," she says. "That's the female fast – from the birth of her pup to her first feeding trip. Because they're fasting, it has to be a true measure of how big her fat reserves are, and it's two full days longer in the area of decline, 10.5 days at Sugarloaf versus 8.5 days at Lowrie."

Taken together, Milette believes her results are inconsistent with the idea that Stellers in the Gulf of Alaska are experiencing nutritional stress, at least during the spring while they're building up fat reserves and in the summer while they're under observation. Problems may still be arising in the fall and early winter, which is why Milette would like to see the observation work continue.

"The only way to truly solve this is going to be lots of resightings to follow along and find out what's happening to the juveniles, and to see if there's a difference in reproductive rates between the two sites," says Milette.

Now on her way to begin a Ph.D. at Memorial University in Newfoundland, Milette intends to be one of those people returning to Sugarloaf in years to come. Apparently, there's something about storms, and tents, and little barren rocks in the North Pacific that grows on one after a while. And at least now, Milette does own a pocketknife.





MARINE MAMMAL RESEARCH

A Newsletter of The North Pacific Universities Marine Mammal Research Consortium

No. 4, 1998

Steller Summers

"Keep your Swiss army knife with you. If the tent gives way we'll have to cut our way out"

Not exactly the words you want to hear from your tent-mate, particularly when the tent itself is perched on the edge of a precipice overlooking the North Pacific, and the wind is roaring over like a freight train, and the supposedly secure wooden tent platform has already begun to rattle and tip. Especially not if the same gale force wind ripping away at the tent frame is also whipping up waves 20 feet high. Particularly especially not if – as was then the case for UBC graduate student Linda Milette – you're new to Alaska, and don't even own a pocket knife.

It was the darkest moment in Milette's whole time on Sugarloaf Island, a tiny rock outcropping in the western Gulf of Alaska. Lacking any other options, however, she rooted around in the kitchen supplies until she found a butcher knife, then hunkered back into her sleeping bag to wait out the storm. By the time the gale abated some 30 hours later, her tent-mate, a technician with years of experience in the field, offered Milette a chance to call it quits, call a chopper and head for home. Milette, however, decided to stick it out. She was there, after all, not for her health, or the existential joys of life on a barren bit of sea-swept rock, but to help shed some light on the mysterious disappearances going on among the island's only other mammalian inhabitants, a herd of Steller sea lions.

From about 1980 onward the Stellers on Sugarloaf, and indeed in all of the western Gulf of Alaska, the Aleutian Islands and the Bering Sea had gone into a steep decline. By 1994, when Milette first set foot on Sugarloaf Island, the worldwide population of Steller sea lions had plummeted from about 300,000 to under 90,000 individuals. No one knew for certain what was causing the decline, but the leading suspect was nutritional stress, the scientific term for starvation. Many scientists – Milette



included – felt that the Stellers simply weren't getting enough to eat.

Long-term studies of related species like California sea lions had shown that when food was scarce – during El Niño events, for example – behavioral changes manifested themselves among the animals. They spent more time out at sea foraging for food and less time on shore nursing their pups. When they were on shore, the animals tended to be more aggressive toward each other and at the same time less active overall.

Unfortunately, performing a similar comparison on Stellers was impossible because no base-line studies of Steller behavior in the western Gulf had been done before the decline set in. Fortunately, however, Steller sea lions in southeast Alaska and northern British Columbia had been completely unaffected by the decline. In these areas Stellers were maintaining and even increasing their populations slightly. The thing to do, Milette reasoned, was to send out two teams of researchers, one to the area of decline, and one to the area where Steller populations were stable,

to see if there were any significant differences in behavior between the two groups that could be correlated to nutritional distress.

Her graduate supervisor, Consortium Director Dr. Andrew Trites, went for the idea, and thus it was that Milette found herself from May to August 1994, sitting 12 hours a day on a rock near a rookery on Sugarloaf Island, noting down every move, every significant shake, snarl and roar of some 30 identifiable Stellers among a herd of more than 100. At the same time, another team of researchers at Lowrie Island in southeast Alaska was noting down the behaviors of a presumably healthy herd of Stellers. In 1995, the two teams, Milette included, came back and did exactly the same thing for another 10 weeks.

The result of these two years of field work was a mountain of data. After two full years of crunching numbers, the results began to sluice out from the data collected, and when they did they were exactly the opposite of what Milette had expected.

"I only found one behavior – the Stellers in the area of decline are more aggressive – that would suggest the animals are nutritionally stressed," says Milette. "Everything else that we found was inconsistent with that prediction."

Milette found that the sea lions on Sugarloaf spent more time nursing their pups and less time at sea searching for food. On the surface, all of these results would seem to indicate that these animals were not experiencing problems obtaining enough to eat, but Milette is nonetheless cautious about jumping to conclusions.

The behavioral differences might merely reflect how far the two sites are from their feeding grounds. Similarly, the fact that pups spend more time

nursing in the area of the decline could indicate that the mothers are actually having a hard time producing milk, and so the pups are sucking away in a vain attempt to get enough sustenance.

There is one result, however, about which Milette is not at all diffident. "The longer perinatal period is the big one," she says. "That's the female fast – from the birth of her pup to her first feeding trip. Because they're fasting, it has to be a true measure of how big her fat reserves are, and it's two full days longer in the area of decline, 10.5 days at Sugarloaf versus 8.5 days at Lowrie."

Taken together, Milette believes her results are inconsistent with the idea that Stellers in the Gulf of Alaska are experiencing nutritional stress, at least during the spring while they're building up fat reserves and in the summer while they're under observation. Problems may still be arising in the fall and early winter, which is why Milette would like to see the observation work continue.

"The only way to truly solve this is going to be lots of resightings to follow along and find out what's happening to the juveniles, and to see if there's a difference in reproductive rates between the two sites," says Milette.

Now on her way to begin a Ph.D. at Memorial University in Newfoundland, Milette intends to be one of those people returning to Sugarloaf in years to come. Apparently, there's something about storms, and tents, and little barren rocks in the North Pacific that grows on one after a while. And at least now, Milette does own a pocketknife.



Hormonal Surges

Dealing with hormones can be complicated. Just ask any adolescent. It becomes especially tricky when the hormones belong not to people, but to pinnipeds. Just ask Tania Zenteno-Savin. Her Ph.D. thesis – researched and written under the supervision of University of Alaska Fairbanks Professor Michael Castellini – examined the role played by hormones in the physiology of pinnipeds, including Steller sea lions. It was, according to Zenteno-Savin, not at all a simple undertaking. "These little molecules do so much, accomplish so many different things."

For her thesis, Zenteno-Savin focused in on three vasoactive hormones – AVP, ANP, and ANG II – found in the blood plasma. In humans and other mammals, these compounds perform a wide variety of functions: they moderate the resistance of blood vessels, and thus affect heart rate; they participate in the maintenance of water and electrolyte balance; they control to some extent the responses governing hunger and thirst; and they may even play a role in moderating mammalian learning responses. Most intriguing of all, these three hormones might also provide some insight into the ongoing decline of Steller sea lions.

Steller sea lion populations in the Bering Sea and western Gulf of Alaska have been declining since the early 1980s, and according to a 1996 census are now down to under 75,000 animals. A food supply problem is thought by many scientists to lie at the root of the decline, but field observations of Steller rookeries have reported animals that, to human eyes at least, appear completely normal.

In human beings, studies have shown that individuals suffering from eating disorders like anorexia and bulimia have elevated levels of certain blood hormones. Zenteno-Savin felt that Stellers suffering from nutritional stress might well manifest similar changes in their blood hormone levels. To test this hypothesis, she collected and analyzed blood samples from nearly 200 Stellers at various rookeries and haulouts in southeast and northwest Alaska.

Zenteno-Savin also worked with the captive Stellers at the Vancouver Aquarium to determine if either fasting or a food restricted diet had any effect on the animals' blood hormone levels. For the food restricted part of the experiment, 4 juvenile Stellers had their rations cut from 8 kg to 4 kg of herring



per day for a period of 4 weeks. Their blood was sampled before the dieting began and at weekly intervals as it progressed. For the fast, two Stellers were taken off food completely, though water and ice cubes were freely available. Blood samples were taken after 0, 3, 7 and 14 days.

Zenteno-Savin's results were tantalizing, but not completely satisfying. One of the blood hormones, ANG II, did seem to respond to changes in the captive sea lions' diets. ANG II levels more than tripled over the 14 days of fast (of the other two, AVP was unaffected, while ANP seemed to decline, but not significantly). On the surface, this would seem to indicate that blood hormones do provide some gauge of how well a Steller has been eating. Unfortunately, Zenteno-Savin's other work with blood hormone levels in the wild comes in and muddles things up again.

In wild Stellers, Zenteno-Savin found that ANG II levels seem to vary all over the scale, with the levels in animals in the thriving southeast actually coming in higher than in the Aleutians. As well, though ANG II levels certainly rose over the course of the fast, their final value in absolute terms was well within the levels found among wild Stellers.

Zenteno-Savin's gut feeling is that her results hold a valuable clue to the Steller decline, but she also believes it will take a bit more effort to ferret out their full significance. "The hormones are doing so many things that we're just beginning to understand how they function, particularly in marine mammals where there's still so much that we know so little about."

As with so many things in adolescence, it seems, it's going take a few tries before things begin to fall into place.

New Blood

Four new Steller Sea Lions pups now make their home at the Vancouver Aquarium and are working with researchers to help figure out why some of their brethren in Alaska are in such dire straits. The two males and two females – named Kodiak, Timber, Hazy and Sitka after haulouts in the Gulf of Alaska – arrived in late June, after being captured off Cape Scott near the northern tip of Vancouver Island. A mere 20 kilograms when they arrived, the pups have since grown to 60 kgs, progressing from formula to liquefied fish to solid herring.

Thanks in part to the knowledge gained by the Aquarium in raising young Stellers, animal health technician Gwyneth Shephard has had no trouble training the new arrivals to take part in several ongoing Consortium experiments designed to understand the energy requirements and the relationship between growth and the different types of fish they eat. Metabolic trials – under the direction of Consortium researcher Dr. David Rosen – are now an expected part of the pups' weekly routine while morphometric measurements – with trainers measuring the pups' length and girth – are conducted twice weekly, again with the pups' full cooperation.

The youngsters have also participated in three different fasting trials, adding greatly to researcher Dr. Lorrie Rea's store of data on Steller blood chemistry and the changes it undergoes in response to food limitation. Such studies have also helped to understand how these creatures adapt their metabolism to periods of low food intake. Active metabolic trials, where the animal's metabolic rate is measured while it exercises in a large swim mill, are planned for the coming months. The pups will also soon experience the chill of their natural seas. A newly installed water-refrigeration unit will enable Consortium scientists to study the effects of cold temperatures on energy demands (the equipment can bring the water temperature down to a frosty 35°F/1.7°C). The pups will also be taking part in a series of new experiments, including tracing hormone levels through saliva samples, the effects of swimming and diving on heart rate, and tests of their visual abilities.

According to Shephard, the pup's sheer trainability should allow Consortium researchers to greatly augment the data obtained working with the previous six Stellers. "We're getting a lot of information that just wasn't possible with the last group," says Shephard. Practice, it seems, makes perfect.



Kodiak, one of 4 new Steller sea lion pups that joined the research team this summer.

Other Studies

A trawl vessel was chartered to assess the types of fish and the relative quantities available to Steller sea lions near their major summer breeding area in Southeast Alaska. Consortium researchers also collected over 400 fecal samples to determine what sea lions were eating, and tracked 10 mature females at sea with satellite tags to determine where and when they were eating. This study will provide valuable insights into the foraging ecology of Steller sea lions and the role that food availability might be playing in the population decline.

Results from the captive feeding studies at the Vancouver Aquarium are being published in the scientific literature. One recently published paper looked at the amount of energy used to digest meals of different sizes (called the heat increment of feeding). Other studies being prepared for publication include the effect of squid consumption on sea lion physiology, the triggers of metabolic depression, and the much-anticipated results of the pollock diet experiment. Results of these and other studies carried out by researchers at Oregon State University, and the Universities of Alaska, British Columbia and Washington will be highlighted in future newsletters.

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The North Pacific Universities
Marine Mammal Research Consortium
The University of British Columbia
Hut B-3, Room 18
6248 BioSciences Road
Vancouver, BC V6T 1Z4 Canada
Tel: (604) 822-8181
Fax: (604) 822-8180
e-mail: consortium@zoology.ubc.ca

The North Pacific Universities Marine Mammal Research Consortium

ANNUAL REPORT

1996-1997

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THE CONSORTIUM

In the summer of 1992, John Roos, Vice President of the Pacific Seafood Processors Association, on behalf of a group of representatives of the fishing industry, requested Pacific northwest universities to submit proposals for research concerned with the impacts of fisheries on Steller sea lions. From that request, the *North Pacific Universities Marine Mammal Research Consortium* was formed with four participating institutions: the University of Alaska, the University of British Columbia, the University of Washington, and Oregon State University.

The mission of the Consortium is to undertake a long term program of research on the relation between fisheries and marine mammals in the North Pacific Ocean and Eastern Bering Sea. Studies will focus initially on the biology of the Steller sea lion and could include research on the effects of species interactions and oceanographic conditions on changes in sea lion abundance. The scope could subsequently be broadened to include other marine mammals and possibly sea birds.



Peter Anthony Larkin
1924 - 1996

Peter Larkin was known internationally for his significant contributions to the areas of fisheries science, resource management, and science policy. Following his retirement from the University of British Columbia in 1989, he worked to establish the North Pacific Universities Marine Mammal Research Consortium and continued to devote his efforts to furthering the goals of the Consortium until his death on July 10, 1996. His sage and generous counsel will continue to assist in shaping the dialogue between the many Consortium stakeholders.

THE PROBLEM

Over the past few decades, major changes have occurred in the abundance of seals, whales and sea birds breeding in the North Pacific. In Alaska, harbor seal numbers are greatly reduced, northern fur seals are *depleted*, while Steller sea lions are *threatened* and may soon be declared *endangered*. Similar declines have been reported in some seabird breeding colonies. In British Columbia, Steller sea lion numbers appear stable, but harbor seal populations have increased rapidly. Further south, striking increases are being observed in the range and abundance of elephant seals and California sea lions.

Such large scale changes may be a natural phenomenon or may be connected with similar changes occurring concomitantly in a number of commercial fisheries. All told, they stand to impact the economic development of commercial fisheries throughout the North Pacific.



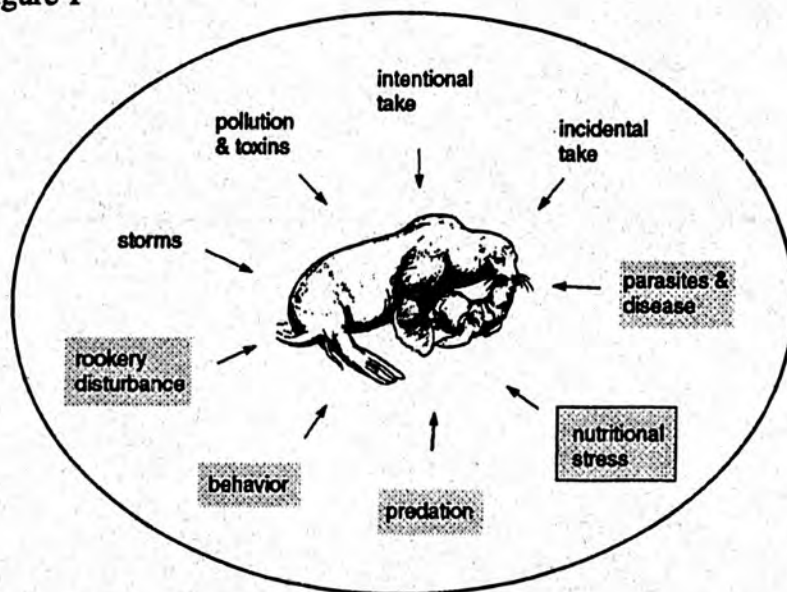
BACKGROUND

Why Steller sea lions have declined in Alaska continues to remain unresolved. Possible causes shown in the shaded regions of Figure 1 include increased incidence of parasites and disease, predation by killer whales, nutritional stress through competition with man or other species for food, or nutritional stress caused by natural and/or human-induced changes in the abundance, quality and distribution of prey. Other factors that may be contributing to the population decline include meteorological changes (i.e., frequency of storms), pollution and toxic substances, entanglement in marine debris, and incidental and intentional take by man.

For the most part, data to assess each of the possibilities is currently limited. Whether the decline is caused by a single factor or a combination of all of the above is a matter of scientific debate. However, considerable research is being focussed on the nutritional stress hypothesis.

In 1990, the Steller sea lion was listed as a *threatened* species under the *US Endangered Species Act*. In October 1995, the National Marine Fisheries Service announced in the US Federal Register their intention to relist the Steller sea lion as two distinct populations, maintaining those east of Prince William Sound as *threatened*, and relisting those to the west as *endangered*.

Figure 1



Funding for the research program of the Consortium is provided by the Pacific Marine Science Foundation, formed especially for that purpose. Contributions to the Foundation have come from other foundations, federal grants and a wide spectrum of donors representative of the industry.

The research program is overseen by a Scientific Advisory Committee with representatives of universities, industry, and government agencies. A Research Committee, composed of the research leaders at the various universities, is responsible for preparing a proposal for research each year and for reporting on progress to the Scientific Advisory Committee.

The Consortium has been greatly aided in its work by the guidance and assistance provided by the United States National Marine Fisheries Service, the Alaska Department of Fish and Game, Fisheries and Oceans Canada, the National Fish and Wildlife Foundation and the Vancouver Aquarium.

Consortium researchers have completed their fourth full year of research. This report reviews the accomplishments from April 1996 to March 1997, and briefly sketches the work proposed for the 1997-98 fiscal period.

Future contributions of the Consortium will lead to better understanding of the population biology of Steller sea lions, and in due course, to other marine mammals of the North Pacific. The interactions of fisheries and marine mammals are the subject of intensive research in many parts of the world, and will be a major focus of research in the North Pacific for many years to come. The Consortium brings university resources to help resolve the issues at hand.

The Marine Mammal Research Unit of the Fisheries Centre at the University of British Columbia administers the Consortium. Core staff of the Consortium consists of a Research Coordinator (Dr. A.W. Trites) and an Administrative Manager (P. Rosenbaum). Dr. P.A. Larkin oversaw the administration of the Consortium until his death in July 1996.

THE FIVE YEAR RESEARCH PLAN

In January 1993, the Consortium developed a five year research plan to study marine mammal / fishery interactions in the North Pacific: most notably, the effects of commercial fisheries, species interactions and oceanographic conditions on changes in sea lion abundance. The program contains three components: 1) field studies, 2) captive studies and 3) data analysis and laboratory studies. The essence of the field studies is to study and contrast a healthy sea lion population with a declining population. Captive studies on Steller sea lions held at the Vancouver Aquarium are providing data that can not be established in the wild about the nutritional requirements of sea lions. They also provide a means for testing and developing new techniques for studying sea lions in the wild. Analysis of historical data sets and development of new laboratory techniques for processing biological samples comprise the third group of studies.

The studies are a balance of short term and long term projects designed to test the various hypothesis that have been put forward to explain the decline of Steller sea lions (see Figure 1). The studies are integrated and draw on the expertise and talents of university based physiologists, ecologists, marine mammalogists, fisheries specialists and oceanographers. Only a concerted effort and a commitment to long term research will determine the causes of changes in the North Pacific. Solutions are unlikely to come quickly and need a concerted effort. Our five year research plan contributes to this end.



RESEARCH UNDERTAKEN

Predation by Killer Whales

Killer whales have been observed to attack sea lions. The stomach of a dead killer whale that washed ashore in Prince William Sound in the summer of 1992 contained flipper tags from 14 Steller sea lions. Predation on sea lions also has been noted from the stomach contents of stranded killer whales from other parts of Alaska and British Columbia. In view of these findings, a study was begun in 1993 by L. Barrett-Lennard (UBC) and a team of co-investigators to determine whether killer whale predation could significantly affect sea lion numbers. Results of their research are contained in a 1995 report titled *The impact of killer whale predation on Steller sea lion populations in British Columbia and Alaska*.

The authors surveyed mariners for accounts of predatory attacks on Stellers, compiled the available diet information from the stomachs of 22 stranded whales, estimated killer whale abundance from photographs, and developed mathematical computer models to examine whether killer whale attacks could significantly affect Steller sea lion numbers. They concluded that predation by the 258 marine-mammal-eating-type of killer whale (called 'transients') may account for a significant portion of the total annual mortality of sea lions in Alaska and British Columbia. When sea lion populations exceed 100,000, the effects of killer whale predation on sea lion dynamics appears minimal. However, at levels of 50,000 sea lions or fewer, the effects are more significant, and may even be sufficient to drive a population decline.

The authors conclude that killer whales did not cause the sea lion decline, but may now be a significant contributing factor. The model suggests that as many as 18% of the sea lions that die each year in Alaska are taken by killer whales. What is killing the other 82% of the missing Steller sea lions remains unanswered.

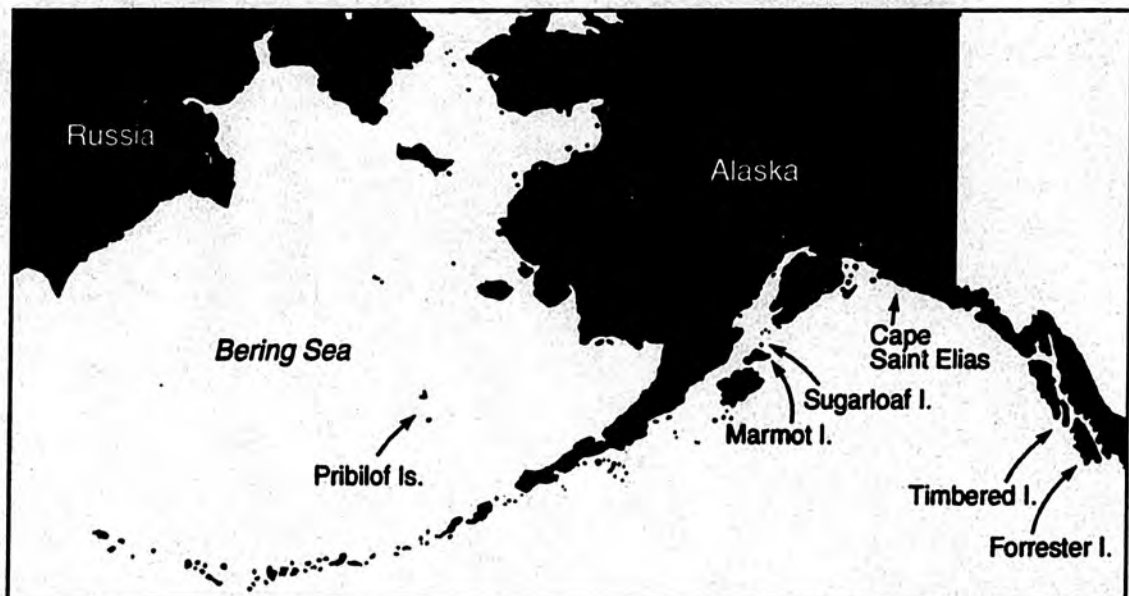
Human Disturbance and Behavioral Changes

Steller sea lions are easily scared off their rookery and haulout sites by humans. While animals commonly return after having been disturbed, it is not clear what the effect of prolonged or repeated disturbances might be on Steller sea lions. The close proximity of fishing vessels or efforts to capture and study Steller sea lions in the wild might therefore be a contributing factor to the population decline.

For the past four years, numbers of pups, juveniles, females and bulls were counted daily at two breeding sites at Forrester Island in a collaborative study with the Alaska Department of Fish and Game. The daily counts began in May before the breeding females return to the rookery, and ended in August after they have left with their pups. One of the two sites was repeatedly disturbed for two years by researchers conducting independent studies. The other remained relatively undisturbed during the entire time period. Preliminary results by Dr. A. Trites (UBC) suggest that human disturbance may cause females and pups to abandon the rookery earlier in the breeding season than they otherwise would.

Behavioral observations in 1994 and 1995 contrasted reproductive behavior of Steller sea lions at two sites: Forrester Island, where sea lion abundance has been stable or increasing, and Sugarloaf Island, where sea lion numbers are in decline (see Figure 2). The study by L. Milette (UBC) measured behaviors that have been reported to change during periods of nutritional stress, namely: activity budgets, maternal attendance patterns (time spent ashore and at sea), maternal investment (number of suckling juveniles, time spent with pups) and male investment (length of bull tenure, number of copulations).

Figure 2



Preliminary results suggest that activity budgets and maternal attendance patterns differ between the two areas. However many of the observations are not consistent with the hypothesis that the declining population is nutritionally stressed during the summer. For example, in the area of decline, females spend more time nursing their pups and have a significantly longer perinatal period compared to females from the abundant population of southeast Alaska. Feeding trips were shorter in the area of decline, but it is not known whether this was due to a difference in prey abundance or location of feeding areas. The amount of time that females spend onshore with their pups decreases at both sites as the pup grows older. Females also appear to spend the same amount of time in close proximity to their pups at each of the sites. Male investment data have not yet been examined, and additional results for female behaviors are also pending.

A second summer study was initiated in June 1996 at a non-breeding (haulout) site at Timbered Island in Southeast Alaska (see Figure 2) to quantify the activities and behaviors of animals that elect not to return to the breeding areas (rookeries). Roughly 45% of Steller sea lions use haulouts during the summer, yet relatively little is known about this group of animals. Our pilot study was designed to monitor the juvenile age class and document summer behaviour, noting the incidence of copulations and the process of weaning. With financial assistance from the National Fish and Wildlife Foundation, a team of biologists will be returning to Timbered Island in May 1997, and a second team will be sent to another nonbreeding site in the area of decline.

A third behavioural study was initiated in January 1995 by B. Porter (UBC) to document the behavior and activity budgets of immature animals at a winter haulout site, Cape St. Elias (Figure 2). In January 1996, the study was expanded to contrast winter behaviors and activity budgets of a declining population at Marmot Island with an increasing population at Timbered Island in Southeast Alaska. Unfortunately observations ceased in the area of decline when human disturbance caused animals to abandon the Marmot site. With financial assistance from the National Fish and Wildlife Foundation, biologists returned to Marmot (January - March, 1997) to gather the data needed to complete this study.

The winter study is considering whether females are able to adequately nourish their pups during lactation, and whether weaned juveniles are able to successfully forage on their own. Changes in the sex and age composition of the haulout population were noted over the winter months, and haulout behaviour and activity budgets of pups, yearlings and juveniles



were recorded through scan and focal animal sampling. A significant correlation between numbers of mature females on shore and numbers of immatures present, suggests that a high proportion of immatures are not fully weaned 3-5 months prior to the start of the breeding season. Observers have also noted a high incidence of aborted fetuses.

Both summer and winter behavioral observations are designed to test for signs of nutritional stress and to detect aberrant behavior at various densities. Field support and assistance is being provided by the Alaska Department of Fish and Game.

Disease & Parasites

The role of infectious diseases in the decline of Steller sea lion populations has yet to be fully evaluated. It is known however that disease can degrade general health, reproductive capacity, and survival of individuals, but the impact on population dynamics is not clear.

A collaborative study by Dr. F.M.D. Gulland (Marine Mammal Centre, California), Dr. T. Spraker (Veterinary Diagnostics Lab, Colorado), D. Calkins (ADF&G) and Dr. A.W. Trites (UBC) was proposed in 1996 to test the hypothesis that disease is causing the decline of Steller sea lions through reproductive failure. This study, planned for 1997-98, will examine reproductive data and use mathematical models to explore whether the rates of decline of Steller sea lions in time and place are consistent with the transmission of a sexually transmitted disease. The study will also determine what pathogens Steller sea lions have been exposed to in the increasing and decreasing areas using serum samples collected over the past decade.

Nutritional Stress

D. Calkins and E. Goodwin from the Alaska Department of Fish and Game concluded that Steller sea lions were physically smaller in the mid 1980s compared to sea lions sampled in the mid 1970s, a conclusion further supported by morphometric measurements of sea lions caught in the trawl fisheries. Both findings suggest that sea lions may not have obtained adequate nutrition during the 1980s. Simulation studies by the National Marine Fisheries Service (A. York) further suggest that young sea lions may have had a higher incidence of mortality. These and other findings have led to the hypothesis that a shortage of food during the winter may cause pups to die of starvation or other problems associated with food stress.

This hypothesis has received major attention by government agencies as well as by Consortium Researchers. Our approach is four fold: (1) verify changes in body size; (2) determine energy requirements; (3) examine how diet may have changed between sites and over time; and (4) determine whether the forage base has changed with time and, if so, explore whether the change is related to fisheries and/or natural changes in the ecosystem.

Verifying Changes in Body Size

Existing morphometric data are currently being re-analyzed by the Alaska Department of Fish and Game. We are attempting to collect additional data from sea lions taken in the subsistence harvest in a project coordinated by Dr. A. Springer (UA). Increasing numbers of samples and morphometric measurements are being provided to researchers by subsistence hunters.

Another approach to determine how conditions may have changed from previous decades is to examine the annuli of sea lion teeth as proposed by Dr. D. Sampson (OSU) for 1997-98. Growth records and chemical signals embedded in the teeth of Steller sea lions will be examined between sites and over time to test whether changes may have occurred in the age of weaning or the age of first lactation. A pilot feasibility study will begin in the coming year pending budgetary approval.

A pilot study was initiated with the subsistence hunters on St. Paul Island (Pribilof Islands, Fig. 1) in July 1995 to measure the lengths of subadult males taken in the northern fur seal harvest, and to compare them to the mean lengths of fur seals harvested in earlier years. Such a comparison may provide insight into the general health of the ecosystem of fur seals and Steller sea lions, and may also offer insight into why the Pribilof fur seal population has failed to recover. It seems likely that if Steller sea lions are physically smaller, then northern fur seals should also be physically smaller.

A considerable data base of body length measurements already exists for the Pribilof population. From 1933 to 1956, 1.6 million males of unknown ages were measured during the harvest. An additional 36,000 males of known ages were measured from 1943 to 1983. A comparative set of length measurements has not been collected from the harvest since 1983. In 1995 and 1996 we measured and aged over 400 young males per year. Preliminary findings suggest that northern fur seals are indeed smaller today, and that the carrying capacity of northern fur seals from the Pribilof Islands may now be half of what it was half a century ago. This research will continue in 1997.



Determining Energy Requirements

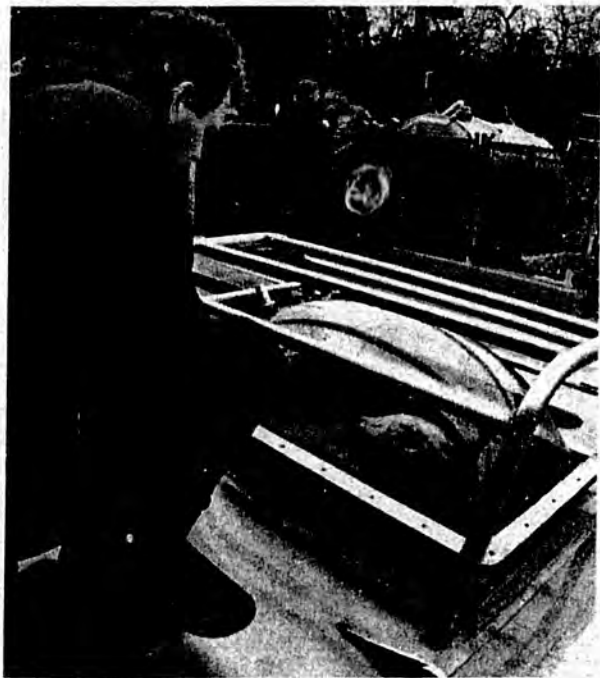
In 1993, three male and two female sea lion pups were taken from a Canadian rookery and transferred to the Vancouver Aquarium. In 1994, an orphaned female pup joined the research group.

Studies on these six captive animals are enabling determination of: (1) metabolic rates, (2) nutritional requirements, (3) digestive efficiency of different diets (such as pollock and herring), and (4) the relationship of diet to growth, blubber thickness, and reproductive maturation. In addition, we can (5) identify what and how much sea lions are eating in the wild by feeding the captive animals different foods and observing which bony hard bits survive the digestive process to pass out in scats. The culmination of these studies will be a mathematical model that considers seasonal and annual activity budgets for sea lions at both the individual and population levels, and makes predictions about the amount of food they need.

Baseline or resting metabolic data have been collected since October 1993 via direct gas exchange measurement (using an open circuit respirometer). The studies being conducted by Dr. D. Rosen (UBC) are showing how the energy requirements of the Stellers change with both age and time of year. Two important patterns have emerged. The first is that resting metabolic rate declines with age, an inevitable consequence of mammalian growth. Younger animals grow faster, and have consequently greater energy requirements than do older animals. However, there is also an apparent seasonal pattern in metabolic rates. Data collected since 1993 indicate that metabolism drops sharply as summer approaches, before increasing again in the fall. This implies that young Steller sea lions may have unusually low food requirements during certain times of the year.

The second component of the metabolic studies is experimental manipulations. In January 1996, a swim mill was installed at the Vancouver Aquarium to measure the energetic costs of swimming. It was constructed at cost by BC Packers with financial assistance from the Alaska Science and Technology Foundation. Studies on the combined effects of exercise and water temperature are awaiting the necessary funds to construct and install a water temperature control unit.

Studies are being undertaken to determine the physiological effects of changes in the type and quantity of diet. One set of experiments examines how changes in the amount of food affects body mass, body composition, and metabolism. Other experiments are examining how different types of prey (such as herring, pollock, squid, cod, Atka mackerel, and salmon) affect



the sea lions. Although the sea lions are allowed to eat as much as they want, they appear unable to maintain body mass when switched to a lower calorie prey type, such as squid or pollock. They appear to partially compensate for this change by lowering their metabolic rates to conserve energy.

A co-operative research project with Dr. L. Rea (National Marine Fisheries Service) has been examining the effect of fasting and reduced food intake on blood chemistry and body composition in the sea lions. Differences in several blood parameters have been observed between Steller sea lions in the areas of declining and stable populations. Some of these differences may be indicators of nutritional stress in certain populations, but no comparative data from otariids (sea lions and fur seals) is available. Placing the captive Steller sea lions on fasts of up to 14 days and a 30 day period of 50% food restriction provides comparisons to blood profiles obtained from wild sea lions. To date, four animals have completed the reduced food intake trials, and two have undergone fasts. Preliminary results suggest that some of the differences in blood chemistry observed in the wild sea lions are consistent with short-term fasting and may be indicative of nutritional stress.

Another set of experiments is considering how efficiently sea lions use the available energy from different prey types. Digestive efficiency (how much of the food is actually processed) is being measured using the dietary manganese method. Concurrent work has also begun to determine the effect of prey type and meal size on the amount of ingested energy which is ultimately available to the sea lion (the heat increment of feeding). Results indicate that lower quality prey, such as pollock, requires more energy to digest than a higher quality prey, such as herring, and that proportionally more energy is lost from larger meals. All of the experiments to date have been with resting sea lions, but work is planned to examine the effects of swimming exercise on the metabolism and digestive efficiency of the sea lions.

Examining Changes in Diet and Foraging Success

Enumerating prey remains in scats is the best nondestructive means presently available to determine what sea lions are eating. Since 1993, Dr. A. Trites (UBC) has obtained over 1,500 scat samples in a collaborative project with Alaska Department of Fish and Game in Southeast Alaska. The 326 scats collected in the summer and fall of 1993 showed a surprisingly high proportion of pollock in the diet. Other species in high abundance included cod, herring, salmon and arrowtooth flounder. An extended effort has been underway to obtain samples four times per year. Particular attention is being paid to whether diets of animals using the male dominated



haulouts differ from those using rookeries, given that future dietary studies concentrated on haulout animals would cause minimum disturbance.

Since 1993, Dr. A. Springer (UA) has enlisted the aid of subsistence hunters to obtain stomach and tissue samples from 67 animals killed on the Pribilof Islands. Most of the samples have come from subsistence hunting in spring, fall, and winter. Tissues have been provided to the National Marine Fisheries Service for genetic studies to identify the stock affiliation of animals in the harvest. The information is becoming ever more relevant to management decisions for sea lions as the population continues its overall decline. Stomach contents are being identified and tissues are being analyzed using stable isotopes for dietary information. In cooperation with the National Marine Fisheries Service, the program has recently expanded into the Aleutian Islands.

Ratios of carbon and nitrogen stable isotopes that accumulate through the food chain are being measured by A. Hirons and Dr. D. Shell (UAF) in whiskers and tissues collected over the past 48 years. An identified shift in isotope levels would support the hypothesis that a shift in diet may have played an important role in the recent population declines.

Vibrissae from pup, subadult and adult Steller sea lions have been and continue to be analyzed from the southeast, central and western Gulf of Alaska, the Aleutians, and the Pribilof Islands (Bering Sea). A strikingly similar pattern is expressed by the stable carbon and nitrogen isotopes in animals from the Gulf of Alaska. The oscillating pattern of isotope ratios seem to reflect seasonal migration between regions of isotopic difference. Some sea lions sampled in the Bering Sea do not exhibit these oscillating patterns but do show an isotopic shift along the vibrissae which appears to correspond to long-term geographic movement outside the Bering Sea. Regional isotopic signatures are beginning to emerge for areas of the Gulf of Alaska and the Bering Sea as more prey and mammal data are being compiled. Studies are continuing on the rate of whisker growth and isotope uptake of the captive sea lion population at the Vancouver Aquarium.

Analyses of current and archived tissues (1950-1996) suggest there has not been a trophic shift resulting from a change in major food sources during the past forty-seven years. However, a significant change in Carbon-thirteen, originating from the base of the food web, appeared in the mid-1970s. This change was not localized or species-specific, and is seen in Steller sea lions, northern fur seals and harbor seals from SE Alaska through to the Pribilof Islands. In light of other physical and

biological data, the isotopic data suggest a decrease in the carrying capacity of the North Pacific ecosystem.

Preliminary analysis of osmoregulatory hormone concentrations by T. Zenteno-Savin (UAF) suggest that the anti-human sera used in the hormone assays cross-react with hormones from seals and sea lions, and that circulating levels of the hormones analyzed in several species of pinnipeds are within ranges reported for humans and terrestrial mammals. It is particularly interesting that Steller sea lions sampled in Alaskan waters had a significantly elevated level of atrial natriuretic peptide. The possible relationship between dietary stress and elevated hormone levels is being evaluated by comparing data from wild animals with hormone concentrations in Steller sea lions maintained under a known diet regime at the Vancouver Aquarium.

Since 1993, R. Andrews (UBC) has been developing and successfully field-testing a portable data logger for attachment to free-living Steller sea lions to record location, diving depth, swim speed, and changes in stomach temperature (*i.e.* an index of feeding activity). Dramatic drops in stomach temperature indicate prey ingestion events, and have provided the first conclusive record of foraging by a wild sea lion. Because of the difficulty of recapturing adults, a remote-release device was developed in 1994 to recover the backpack instruments and reduce the amount of disturbance to the sea lions, both for the instrumented individual and for the entire rookery. Eight adult females were captured and instrumented in 1994, but none were captured in 1995. In 1996 two adults were captured in southeast Alaska before the summer field season was cancelled due to the grounding of the sister research vessel working the Aleutian Islands. The comparative study between declining and increasing populations will resume in June 1997.

To date, the stomach temperature sensors have shown that feeding trips vary in length from 8 to 50 hours, and that prey are consumed on all trips. However, long periods of time often elapse and large distances are covered between successful foraging events.

The new technology is providing new insights into the relationships between diving patterns and successful foraging activity, and will enable a collaborative re-analysis of data collected by Alaska Department of Fish and Game using satellite-linked time-depth recorders. Further development of the technique should also allow us to quantify the actual amount of prey that sea lions are consuming. Calibrating such a change

in stomach temperature against mass of ingested prey has been underway since 1995 using the captive Steller sea lions at the Vancouver Aquarium.

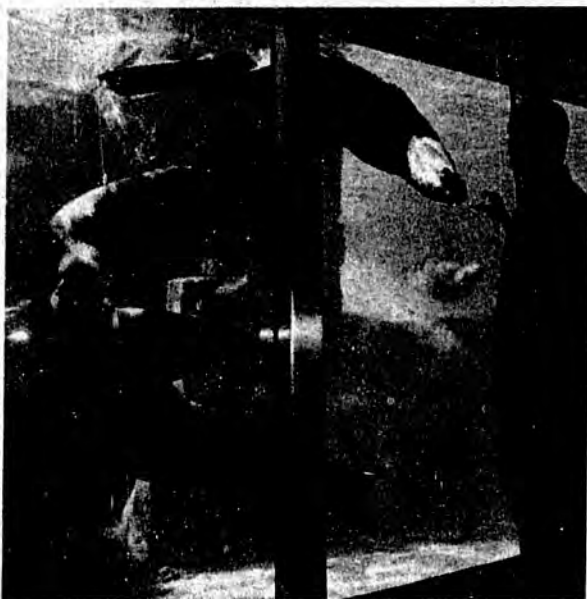
The 1997 study of foraging behavior and energetics of lactating females will be done in collaboration with researchers from Alaska Department of Fish and Game, National Marine Fisheries Service, and Texas A&M University, and will involve the capture of 10 sea lions in Southeast Alaska and 10 in the Aleutians. The electronic devices will be deployed on females that are injected with doubly-labeled water for the determination of energy expenditure.

Changes in the Forage Base

Although the overall number of sea lions in the Gulf of Alaska and Bering Sea has decreased over the past two decades, not all sea lion rookeries have been affected to the same degree. Irregularities between the rookeries could have resulted from differences in seasonal densities of fish or relative amounts of human disturbance.

In 1995, Dr. D. Sampson (OSU) completed his analysis of groundfish fishing activities near Steller sea lion rookeries in Alaska. The study found that large winter catches of pollock occurred near sea lion rookeries that suffered large declines in the early 1980s. However, sharp sea lion declines were also reported in other areas in the late 1980s, where no winter catches of pollock occurred. There was no relationship between the declines and the amount of fishing effort, total catches of groundfish, or catches of Pacific cod and Atka mackerel. It may be that the only way anyone will ever know if there is a relationship between commercial fishing activities and changes in sea lion numbers is by conducting a carefully monitored experiment that heavily fishes in one area while restricting fisheries in another.

Federal funding was awarded to assess the abundance of forage fish in southeast Alaska, where sea lions are abundant and the ecosystem is considered healthy. In June 1997, researchers from the Universities of Alaska and British Columbia will sample fish at sea, track feeding Steller sea lions and assess their diets from scats collected on shore. Results from this in-depth study will be contrasted to those of other investigators from ongoing studies in Prince William Sound and the western Gulf of Alaska. Our ultimate goal is to compare forage fish abundance twice during the year corresponding to important phases in the biology of sea lions: summer, when females are nursing young pups; and winter-spring, when pups are weaned and must begin to feed themselves. Our study in southeast

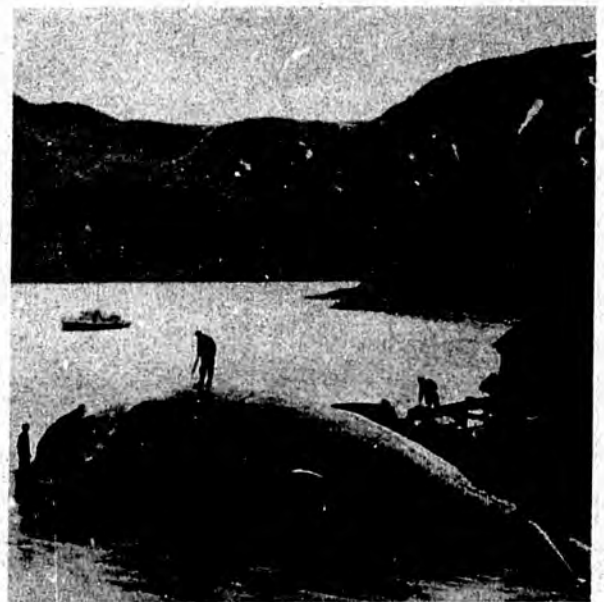


Alaska provides a critical opportunity to test the hypothesis that prey availability is not adequate to support sea lions throughout most of their range. This project will begin in 1997.

Another possible explanation for the decline of Steller sea lions is that an ecosystem shift changed the food base in the North Pacific in the mid 1970s. Dr. A. Springer (UA) is examining the hypothesis that mass removals of whales from the North Pacific contributed to ecosystem change and declines in the abundance of pinnipeds and seabirds. Removals of whales, plus the collapse of Pacific Ocean perch, herring, and yellowfin sole stocks during the same interval in the eastern Bering Sea and Gulf of Alaska (1950s-1960s), resulted in the rapid loss of several million tons of biomass from this region. Such an abrupt change in biological constraints in the system may have had cascading effects that led to new patterns of energy flow through food webs of relevance to other species at higher trophic levels, and could have been the cause of recent declines of sea lions, harbor seals, fur seals, and certain seabirds.

The analysis of the large-scale slaughter of whales in the North Pacific in the 1950s and 1960s just prior to the beginning of the increase in pollock and the decline of sea lions is approaching completion. The harvests of whales in the North Pacific released a substantial amount of biomass to other consumers and reduced predation pressure on certain species, some of which, such as pollock, also stood to benefit from the increase in prey resources. When added to equally large changes resulting from the removals of herring, yellow fin sole, and Pacific Ocean perch during the same interval, the aggregate disturbance could have contributed to the development of a less diverse community and food web structure, an increased sensitivity of the community to variability in the physical environment, and the changes of concern today.

Another hypothesis under consideration is that ecosystem change resulted primarily from variability in patterns of weather and climate, particularly as related to the Aleutian Low pressure system. According to a recent forecast, the NE Pacific climate will cool through the coming decade and enter a "cold" regime by about the year 2005, characterized by conditions that prevailed in the 1950s-1970s. Biological correlates of atmospheric regime shifts continue to be discovered over a wide part of the North Pacific and Bering Sea. These include broad scale changes in primary and secondary production, production of several species of salmon and forage fishes, and the production and abundance of certain species of seabirds and marine mammals. Thus, the ecosystem structure and function may respond to the change in atmospheric forcing.



Dr. Springer is also collaborating with other investigators to obtain core samples from anoxic basins in the Bering Sea and Gulf of Alaska to determine long-term (100+ year) records of variability of forage fish populations preserved in sediments. A pilot program in the Bering Sea has revealed an abrupt decline in the abundance of one species of forage fish, the prickelback *Lumpanella* spp., in the mid-1970s, concurrent with the regime shift in the North Pacific. Investigators using traditional net-sampling techniques found that *Lumpanella* and other forage fishes, including capelin, also declined in the Gulf of Alaska during the same time.

Lumpanella is an important prey of sea lions in the Kurile Islands, and could have been important in the eastern North Pacific, particularly during winter when many other prey species might be less available than they are in summer. For example, summer diets of sea lions in the Aleutians are dominated by Atka mackerel, which are abundant during the summer in shallow water. However, Atka mackerel over-winter at depth off the edge of the continental shelf, and diets of sea lions in the Aleutians in winter have now apparently shifted to miscellaneous species. Thus, *Lumpanella* and other abundant species that inhabit shallow waters year round might be important to sea lions in winter, and their decline in the mid-1970s might have contributed to the decline in abundance of sea lions. Whether or not *Lumpanella* is in fact important prey, it might be a sensitive indicator of environmental change and serve as a proxy for forage fishes of equal or more value to consumers.

Criteria to Protect Stellers

A study was initiated in 1995 by L. Gerber (UW) to review and develop criteria for classifying Steller sea lions as *threatened* or *endangered* under the U.S. Endangered Species Act. It is examining and applying the analytical classification tools suggested by the International Union for the Conservation of Nature (IUCN), including Population Viability Analysis and Minimum Viable Population methods. A final report is expected later this year.

OTHER ACTIVITIES

Consortium Researchers undertook a number of studies in 1996 that fell within our mission statement, but were either not formally proposed in the 1996-97 Research Plan or were completed with outside funding.

The Consortium participated in Kodiak's ComFish in March. In addition, a number of public presentations were made in 1996 about the Consortium's research program by Dr. Trites in Juneau, Cordova, Anchorage, and Kodiak to legislators, fisherman school children and the general public. Further public presentations are planned in 1997.

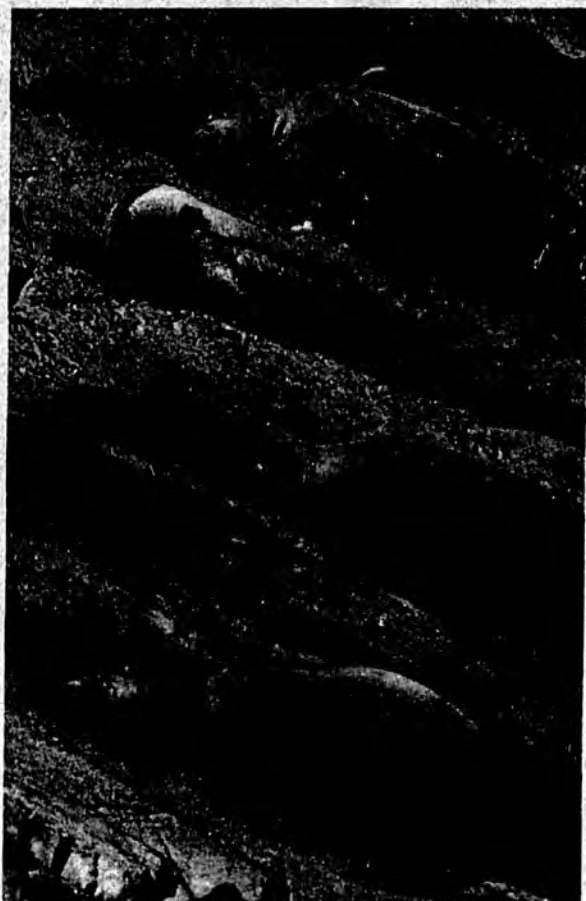
Consortium researchers participated in a number of international forums including: a symposium on the role of forage fish in the ecosystem sponsored by Alaska Sea Grant, a conference on exercise physiology sponsored by the American Physiological Society, a workshop on designing marine reserves sponsored by the University of British Columbia, a working group to estimate the prey consumption by sea birds and marine mammals sponsored by PICES (North Pacific Marine Science Organization), a workshop to plan a scientific program for the Pacific Northwest Coastal Ecosystem Region Study (PNCERS), the National Research Council (U.S.) Committee on the Bering Sea Ecosystem, and a panel of peer reviewers for studies funded by the Exxon Valdez Oil Spill Trustee Council.

The Consortium produced a spring and fall newsletter in 1996 to complement the annual report. The publication is being produced biannually for distribution in February and November.

OVERVIEW

The Marine Mammal Research Consortium was formed to address issues related to marine mammal / fishery interactions in the North Pacific. With this in mind, we have undertaken a solid field program, a strong captive research program, and a major analytical research initiative. Research in 1997-98 will continue with a balance of short-term and long-term projects designed to address and draw conclusions about changes occurring in the North Pacific and about the role that commercial fisheries may have played in causing them. We have mounted a multidisciplinary research program to elucidate the factors responsible for the decline of Steller sea lions in Alaska. Our studies also take into account other issues related to harbor seals, northern fur seals and whales that will attract greater attention in the years to come.

Understanding the causes of change in the North Pacific requires a commitment to long term research. Solutions are unlikely to come quickly and need a concerted effort.



ACKNOWLEDGEMENTS

The Consortium has been greatly aided in its work by the guidance and assistance provided by the US National Marine Fisheries Service, the Alaska Department of Fish and Game, and Fisheries and Oceans Canada. We are particularly grateful for the field support provided by the Alaska Department of Fish and Game.

We extend our thanks to the Vancouver Aquarium and its staff who provide us with research space and expertise in training and caring for our Steller sea lions. We are particularly grateful for the fish donated by J.S. McMillan Fisheries Ltd, UniSea Inc., E.C. Phillips and Son, and Wards Cove Packing Company. As well, we thank the subsistence hunters from the Pribilof Islands and Aleutians East Borough for collecting and providing scientific data from subsistence hunts.

We are also grateful to the members of the Research and Scientific Advisory Committees for the many hours they have spent preparing and reviewing the Consortium research plans.

Finally, we wish to thank our volunteers and the many and varied donors for their support and continued interest. We would particularly like to acknowledge the Alaska Science and Technology Foundation, the National Fish and Wildlife Foundation, the National Oceanic and Atmospheric Administration, and the UBC Office of the Vice President - Research.

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PUBLICATIONS

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FUNDING RECEIVED TO DATE

The Consortium received start up funding in the latter part of 1992 and full year funding in 1993. The fiscal period was changed in 1994 from the calendar year to April 1 - March 31.

1992	(Sep 1 - Dec 31)	\$32,000
1993	(Jan 1 - Dec 31)	\$290,056
1994	(Jan 1 - Mar 31)	\$75,000
1994-95	(Apr 1 - Mar 31)	\$278,124
1995-96	(Apr 1 - Mar 31)	\$300,000
1996-97	(Apr 1 - Mar 31)	\$294,000

LIST OF CONTRIBUTORS

- Alaska Ocean Seafood
Alaska Science and Technology Foundation
Alaska Trawl Fisheries, Inc.
Aleutian Challenger Fisheries
Aleutian East Borough
Aleutian Pribilof Island Community Dvp Assoc.
Aleutian Spray Fisheries, Inc.
Alliance Fishing Inc.
Alyeska Seafoods, Inc.
American Beauty Inc.
American Factory Trawler Assoc.
American Seafoods Company
Anita J. Fisheries Inc.
Auriga/Aurora General Partnership
Bristol Bay Economic Dvp. Corp.
Byrnes & Keller
City of Unalaska
Coastal Villages Fishing Coop.
Dutch Harbor Seafoods Ltd.
E.C. Phillips and Son
Emerald Resources
F/V Alsea
F/V Alyeska, Dutch Harbor Seafoods
F/V Amber Dawn
F/V American Eagle
F/V Argosy
F/V Auriga, Alyeska Ocean, Inc.
F/V Aurora, Alyeska Ocean, Inc.
F/V Defender
F/V Destination
F/V Fierce Allegiance
F/V Great Pacific
F/V Gunmar
F/V Leslie Lee
F/V Nordic Star, Aleutian Spray Fisheries Inc.
F/V Ocean Leader, Inc.
F/V Pacific Monarch
F/V Progress
F/V Royal American
F/V Sea Dawn
F/V Seeker, Inc.
F/V Starfish, Aleutian Spray Fisheries Inc.
F/V Starlite, Aleutian Spray Fisheries Inc.
F/V Starward, Aleutian Spray Fisheries Inc.
F/V Traveler
F/V Viking
F/V Western Dawn
F/V Westward I
Fishing Vessel Owners' Association
Glacier Fish Co. Ltd.
Golden Alaska Seafoods Inc.
Gorton's Seafood
Great Pacific Limited Partnership
Highland Light, Inc.
Icicle Seafoods Inc.
International Maritime Management
J. S. McMillan Fisheries Ltd.
Kodiak Island Borough
Kodiak Salmon Packers, Inc.
Long John Silvers
Marine Safety Reserve
National Fish & Wildlife Foundation
National Fisheries Institute Scholarship Fund
National Oceanic and Atmospheric Administration
Nelbro Packing Co.
Nina Fisheries
North Pacific Fisheries Research Foundation
Northwest Setnetters Assoc.
Norton Sound Economic Dvp. Corp.
Ocean Beauty Seafoods, Inc.
Ocean Dynasty Limited Partnership
Oregon Trawl Commission
Pacific Seafood Processors Association
Pacific States Marine Fisheries Commission
Peter Pan Seafoods, Inc.
Phoenix Processor Ltd. Partnership
Sea Storm Fisheries Inc.
Seafirst Bank
Seattle Fisherman's Exchange
Supreme Alaska Seafoods, Inc.
Trident Seafoods, Inc.
Tyson Seafood Group
UniSea, Inc.
University of British Columbia
Vancouver Aquarium
Victor Seafoods
Wards Cove Packing Co.
Western Alaska Fisheries, Inc.
Westward Seafoods Inc.
Yukon Delta Fisheries Dvp. Assoc.