Summaries of Literature (1960-present): Determinations of Prey Species (as well as some population and fisheries interaction data) for Three Pinnipeds (Pacific Harbor seal, Phoca vitulina, Steller (or Northern) sea lion, Eumetopias jubatus, and California sea lion, Zalophus californianus) on the west coast of North America[1,2,3,4,5]

Sarah Courbis January, 1997
Hatfield Marine Science Center, 2030 S. Marine Science Dr., Newport, OR 97365

TABLE OF CONTENTS

---

[1]Only prey species, population, and fishery information is summarized here; other information was considered irrelevant to the topic and was not included even if it was a main point of the piece of literature being summarized.

[2]General texts were not included in these summaries as it was assumed that they were written using the data in the literature summarized here and in literature previous to 1960.

[3]Some information from sources are secondary citation; generally, secondarily cited information is listed as "results" for the source.

[4]Population and fisheries interaction studies are not an exhaustive sampling but are only included as a supplement to prey species information; an attempt is made to put emphasis on more recent studies, but a sampling of past studies is included to present trends over time; the same error factors were often repeated in literature, so errors are not listed for all sources in which duplications occur; in the interest of brevity, methods et al were not included for studies in which they were not deemed important to the focus of this paper.

[5]In some cases, only an abstract was available for summary.

SECTION I: STELLER SEA LIONS

Part A: Steller Sea Lion Food and Feeding Habits

Spalding, D., 1964

Area: British Columbia coast
Time: 1959, mostly Apr.-Oct.
Method: Stomach content analysis
Number: 393 stomachs (190 had food)
Results:
(**Table 1**--stomach contents found (in Stellers and Harbor seals) each month; **Table 2**--some stomach contents found (in Stellers and Harbor seals) as a percentage of the total contents found; **Table 3**--common and scientific names of prey species)

Over 50% of the diet of Stellers was a combination of squid, clupeids, salmon, rockfish, cod, hake, flatfish, greenling, lamprey, and smelt

Bottom fish and octopus were frequent prey

Rockfish were a main food at all times of year

Herring was a frequent prey

Octopus, dogfish, and salmon were frequently eaten by breeders

Whiting was a major food for non-breeders in summer and winter

Rockfish, salmon, whiting, and hake are main foods in the fall

Herring, salmon, hake, grey cod, whiting, flatfish, halibut, sablefish, lingcod, and rockfish (all commercially valuable species) were 52.5% of Steller stomach contents sampled

Herring: 10% of diet; mostly eaten in winter
Salmon: 5.6% of diet; mostly eaten in summer
Halibut: 1 stomach contained halibut and 1 Steller was observed at the surface eating a halibut

Conclusions:
Abundance of prey may influence feeding patterns; Stellers probably follow salmon influx

Thorsteinson, F. And C. Lensink, 1962

Area: AK
Time: May 27, 1959-July 15, 1959
Method: Stomach content analysis
Number: 382 stomachs; 56 contained food
Results:
(**Table 4**--stomach contents found at 5 locations)

Conclusions:
Stellers eat a wide variety of food but insignificant amounts of commercially important species of fish

There is no apparent difference in stomach contents between sexes

Mate, B., 1973

Area: OR coast
Time: Early 1970's
Method: Stomach content analysis
Number: 1 male
Results:
Found 4 octopus beaks and no fish

Jameson, R. and K. Kenyon, 1977

Area: Lower Rogue River, OR
Time: May, 1973-June, 1976
Method: Visual observations of feeding at surface
Results:
87% sightings -- Lamprey
2% sightings -- Salmonids
11% sightings -- Unidentified

Conclusions:
Lampreys are parasites on salmonids, so Stellers may benefit salmonids by eating many lampreys

Pitcher, K., 1981

Area: Gulf of Alaska from Cape Suckling to Sanak Island
Time: 1975-1978
Method: Stomach content analysis
Number: 250 stomachs, 153 contained prey
Results:
(**Table 5**--prey species found, **Table 6**--top 10 prey species; **Table 7**--frequency of principle prey species found (in Stellers and Harbor seals [from 1980 study])

Contents of stomachs by volume:
95.7% fish
4.2% cephalopods
less than 0.1% decapod crustaceans
less than 0.1% shelled gastropods
less than 0.1% mammals

Predation on salmon and capelin was limited mostly to spring and summer; no salmon were present in the 50 stomachs taken from Oct.-Mar.; 12% of the stomachs taken Apr.-Sept. had salmon and 30% had capelin.

Much squid and herring was eaten in Price William Sound

Walleye pollock was the main prey species, and walleye stocks increased from 1961-1973,75 from 5% to 45% by weight of total demersal fish stocks in the area and are the predominant species

Conclusions:
Walleye pollock may be the top prey of Stellers in this region in part because of walleye's dominance in numbers

Roffe, T. and B. Mate, 1984

Area: Rogue River, OR
Method: Visual obvservations of feeding at surface
Time: Mar.-Aug., 1976-1978
Number: 71 observations

Results:
(**Table 8**--prey species observed each month as a percentage of the total observed)

Conclusions:
Salmonids are probably taken opportunistically

Prey availability affects feeding patterns

Stellers may consume enough lamprey, thereby saving a large enough salmonid population from the parasite, to compensate for their own consumption of salmonids

Roffe, T., 1980

Area: Rogue River, OR
Time: Mar., 1976-Aug., 1979
Methods: Visual observations of feeding at surface; Stomach content analysis
Numbers: 71 observations; 1 stomach (accidentally shot)
Results:
(**Table 9**--Prey species observed each month as a percentage of the total observed (appears to be a copy of Table 8); **Table 10**--Common and scientific names of prey species)

27% sightings: Lamprey
1% sightings: Salmonids

Conclusions:
Steller predation on lampreys may benefit salmonids by reducing the numbers of this salmonid parasite

Salmonids are taken opportunistically, not as a primary target of foraging

Antonelis, G. and C. Fiscus, 1980

Area: Total range (Southern CA-Sea of Okhotsk)
Time: Late 1970's
Method: Summary of previous studies
Results:
(**Table 11**--prey species and population (of Steller, CA sea lion, and Harbor seal))

Conclusions:
Stellers are opportunistic feeders

Lowry, L. et al, 1989

Area: Gulf of AK and Bering Sea
Time: 1970's and 1980's
Method: Previous studies

Results:
One study showed that, in the Gulf of AK, 58% of Steller stomach contents were pollock; in 1951 and 1962, pollock were the 4th ranked prey species of Stellers; in the Bering Sea, Mar.-Apr., 1981, 79/86 Steller stomachs had pollock (pollock were dominant species in 67 stomachs)

Conclusions:
In the Bering Sea, Mar.-Apr., 1976, @97% of food volume and @98% of number of prey eaten by Stellers were pollock

Stellers eat a variety of fish and some octopus and squid

Stellers show some dietary plasticity

Perez, M., 1990

Area: Eastern Bering Sea and Aleutian Islands region
Time: Up to 1987
Method: Summary of literature
Results:
(Table 12--estimated diet composition (of Stellers, CA sea lions and Harbor seals)

Springer, A., 1992

Area: Bering Sea
Time: Early 1990's
Method: Summary of previous studies
Conclusions:
Stellers consume @120,000 tons pollock/yr (pollock are 33% of diet)

O'Daniel, D. and J. Schneeweis, 1992

Area: Eastern Aleutian Islands
Time: Early 1990's
Method: Visual observation
Results:
A Steller ate a glaucous winged gull, Larus glaucescens

Byrnes, P. and W. Hood, 1994

Area: Ano Nuevo Island, CA
Time: July 12, 1992
Method: Visual observation

Results:

A male Steller ate a small CA sea lion

Part B: Steller Sea Lion Populations and Abundance

Mate, B., 1973

Area: OR coast
Time: 1969-1970
Conclusions:
Males are in OR mostly May-Oct (mostly at rookeries); females moving south in Mar. and Apr. usually arrive in OR rookeries in late May; spring breeding season

Some Stellers overwinter in southern OR

Adult males move north in winter and south in summer; females and immature males move south in winter and north in summer

Seasonal numbers of Stellers were about the same in 1971 as in 1969 and 1970.

Pitcher, K., 1981

Area: Gulf of AK from Cape Suckling to Sanak Island
Time: 1975-1978
Results:
Population: @110,000-140,000 in 1975-1978

Area is a center of abundance for Stellers

Roffe, T. and B. Mate, 1984

Area: Rogue River, OR
Time: June, 1976-Oct. 1978
Method: Surveys (at 17 sites)
Number: 5-10/month
Conclusions:
Abundance of Stellers does not correspond to just a single environmental factor; abundance may be related to prey availability

Roffe, T., 1980

Area: Rogue River, OR
Time: June, 1976-May, 1979
Results: Population peaked in summer

Conclusions:
Abundance does not appear to correspond to environmental parameters

Seasonal distribution does not appear to be related to salmonid abundance

Antonelis, G. and C. Fiscus, 1980

Area: Total range (Southern CA-Sea of Okhotsk)
Time: Late 1970's
Results:
(**Table 11**--prey species and population (of Steller, CA sea lion, and Harbor seal))

CA breeding season population: @2200-2300

Conclusions:
Steller population is declining

Stellers are opportunistic predators that are seasonally abundant

Loughlin, T. et al, 1984

Area: CA-Sea of Okhotsk
Time: May-July, 1956-1980
Results:
Population: @235,219 in 1980
@231,237 in 1956-1960

Jeffries, S., 1984

Area: Columbia River estuary (South Jetty to Beaver Terminal)
Time: Apr., 1980-Sept., 1982
Method: Monthly, regional aerial surveys (counting and photos) and ground counts
Results:
Stellers range from San Miguel Island, CA to the Aleutian Islands in the Bering Sea and South to the Sea of Japan

World population: @232,000-262,000

Columbia River population: @80-100 (varies seasonally)

Pupping occurs from mid May-mid June

York, A., 1994

Area: Marmot Island, AK
Time: 1975-1985
Conclusions:
Population declined @5%/yr and fecundity rates decreased @10%/yr from 1975-1985

Lowry, L. et al, 1989

Area: Eastern Aleutian Islands and Gulf of AK
Time: Late 1960's-Mid 1980's
Method: Previous studies
Results:
From the late 1960's to the mid 1980's, overall numbers of Stellers have declined 79% in the eastern Aleutian Islands, 73% in the western Gulf of AK, and 31% in the central Gulf of AK

During the 1980's, Stellers appeared to be under nutritional stress and displayed poor fitness

Conclusions:
Disease is a factor in Steller population declines

Loughlin, T. and R. Merrick, 1989

Area: Bering Sea and Gulf of AK
Time: End of June/early July (peak of breeding season), 1976-1986; pups counted 1st week of July
Method: Surveys
Results:
Steller population declined at every site surveyed from 1976-1986

Conclusions:
Young Stellers begin foraging in Apr., May, and June

Perez, M., 1990

Area: Bering Sea and Gulf of AK
Time: 1959-1987
Method: Summary of previous studies

Results:
Population: @140,000 in 1959-1960
@68,000 in 1985

World population: @245,000-290,000 in 1980
AK population: @200,000 in 1980

Population declined @63% from 1985 to 1989; population declining in all regions of AK

Conclusions:
Stellers probably do not migrate but disperse broadly

Sease, J., 1992

Area: AK
Time: 1960-1989
Results:
Steller populations at some AK rookeries decreased by 63% from 1985-1989 and 82% from 1960-1989

Bickham, J. et al, 1996

Area: Gulf of AK and Aleutian Islands
Time: 1960's-1989
Results:
Population: @240,000-300,000 in 1960's
@116,000 in 1989

Conclusions:
Worldwide population declined @39-48% from the 1960's to 1989; Aleutian Islands population declined by @81%; British Columbia population remained about the same; Southeastern AK population increased slightly

Loughlin, T. et al, 1990

Area: Kenai Peninsula to Kiska Islands (Gulf of AK and Aleutian Islands)
Time: June, 1989
Method: Surveys
Results:
Steller population of adults and juveniles declined 65% from 67,617 in 1985 to 24,953 in 1989; numbers of pups at rookeries also decreased

Conclusions:
No locations surveyed showed significant increases in Steller population

Loughlin, T. et al, 1992

Area: Total range (Russia to CA)
Time: 1989
Method: Surveys
Results:
Population: @68,094 adults and juveniles;
@116,000 world wide

Breakdown of population:

Russia:	10,000 (15%)
AK:	47,960 (70%)
British Columbia:	6,109 (9%)
OR:	2,261 (3%)
CA:	1,764 (3%)

Conclusions:
Steller population declined to @39-48% of the @240,000-300,000 Stellers in 1959

Springer, A., 1992

Area: Bering Sea and Gulf of AK
Time: 1970's-Early 1990's
Method: Summary of previous studies
Results:
(**Figure 1**--population trends (of sea lions and Harbor seals))

Steller population declined by @50-80% at rookeries throughout the Bering Sea and Gulf of AK from the early 1970's to the early 1990's

Stellers were shorter, thinner, and lighter at ages in the early 1990's than in the late 1970's; they display other signs of stress as well

Conclusions:
Steller's population and health declines may be related to food stress

Pascual, M. and M. Adkison, 1994

Area: Gulf of AK and Bering Sea
Time: 1977-Early 1990's

Results:
Distribution: Channel Island, CA to Bering Sea and beyond

Population declined @5%/yr in Gulf of AK and Aleutian Islands from 1977-1985

Declines following 1985 into the 1990's were even more severe

The walleye pollock fishery increased in the 1970's

Conclusions:
The increase in the Walleye pollock fishery in the 1970's may have contributed to the decline of Stellers

Loughlin, T., 1993

Area: Bering Sea
Time: Early 1990's
Conclusions:
In summer, females forage in shallow water close to shore; in winter, females forage in deeper water farther from shore

In Oct. and Nov., Stellers forage mostly along shallow areas of the continental shelf in the southeastern Bering Sea; from Dec.-Feb, high numbers forage in deeper waters in the central Bering Sea

Stellers forage mostly over the continental shelf usually at @4-50m deep

Population has declined throughout most of their range

Sease, J. et al, 1993

Area: Forrester Island, southeastern AK to Attu Island, western Aleutian Islands
Time: June and July, 1992
Method: Aerial and ship-based surveys at 95 previously monitored sites
Results:
Population: @34,844
Conclusions:
Population declined @70.2% from @116,804 in 1975,1979; population declined @4.4% from @36,459 in 1991

Annual rate of decline from 1979-1992 was @9.6% overall and @10.2% for rookeries; annual rate of decline from 1989-1992 was @5.4%.

Decline in population was continuing, though not at as great a rate as up to 1989 (Stellers were listed as a threatened species under the Endangered Species Act in 1990)

<u>Conclusions</u>:
Population of Stellers did not decrease much from 1956-1980

SECTION II: CALIFORNIA SEA LIONS

Part A: CA Sea Lion Food and Feeding Habits

Jameson, R. and K. Kenyon, 1977

Area: Lower Rogue River, OR
Time: May, 1973-June, 1976
Method: Visual observation of feeding at surface
Number: 9 observed (5 with identifiable prey)
Results:
All sightings were lampreys

Conclusions:
CA's prey on lampreys, and this may benefit salmonids by lowering the number of these parasites

Roffe, T., 1980

Area: Rogue River
Time: June, 1976-May, 1979
Methods: Visual observation of feeding at surface (Jan.-June, Nov.); Gastrointestinal tract content analysis
Numbers: 86 observations; 28 gastrointestinal tracts (3 were from strandings)
Results:
(**Table 10**--common and scientific names of prey species; **Table 13**--prey species observed (appears to be a copy of Table 16); **Table 14**--prey species found in gastrointestinal tracts (appears to be a copy of Table 17); **Table 15**--prey species found in gastrointestinal tracts of stranded animals (CA's and Harbor seals)

Breakdown of diet observed and found:
69% Lamprey
19% Steelhead
3.3% Salmon

Lamprey were present in 93% of sea lion stomachs (includes one Steller stomach accidentally collected); 7.1% of CA's stomachs contained steelhead and not lamprey; 46.4% contained lamprey and not steelheads

Conclusions:
CA predation on lampreys may benefit salmonids by reducing the numbers of this salmonid parasite; salmonids are taken opportunistically, not as a primary target of foraging

Roffe, T. and B. Mate, 1984

Area: Rogue River, OR
Methods and Times:
Visual observation of feeding at surface (Jan.-June and Nov., 1976-1979);
Gastrointestinal tract content analysis (Mar. to May, 1978-1979)
Numbers: 86 observed; 28 gastrointestinal tracts
Results:
(**Table 16**--prey species observed; **Table 17**--prey species found in gastrointestinal tracts)

Almost all CA gastrointestinal tracts that contained salmonids also contained lamprey, but many tracts contained lamprey and not salmonids

Conclusions:
Gastrointestinal tract content analysis showed salmon are of only minor importance in CA's diet even though visual observations made salmonids seem more important; salmon are probably taken opportunistically

CA's may consume enough lamprey, thereby saving a large enough salmonid population from the parasites, to compensate for their consumption of salmonids

Prey availability affects CA's feeding patterns

Antonelis, G. et al, 1984

Area: San Miguel Island, CA
Time: Spring and summer of 1978 and 1979
Method: Scat analysis
Number: 224 scats (195 scats had identifiable prey)
Results:
(**Table 18**--prey species found)

Amounts consumed of each species fluctuated between spring and summer and between 1978 and 1979

Conclusions:
CA's are opportunistic feeders and switch feed; CA's are flexible in foraging and fluctuations in consumption of prey species could reflect prey availability

Everitt, R. et al, 1981

Area: Puget Sound, WA
Time: May 1979
Method: Scat analysis
Number: 47 scats (and 1 spewing) (8 scats had identifiable otoliths)
Results:
(**Table 19**--fish otoliths found)

Antonelis, G. and C. Fiscus, 1980

Area: Total range (Mexico-southern British Columbia)
Time: Late 1970's
Method: Summary of previous studies
Results:
(**Table 11**--prey species and population (of CA, Steller sea lion, and Harbor seal))

Conclusions:
CA are opportunistic feeders

Aurioles, D. et al, 1984

Area: Bay of La Paz, Baja CA Sur, Mexico
Time: Sept., 1980-Aug., 1981
Method: Scat analysis (collected monthly except May; all feces were removed each time to ensure one month samples)
Number: 231 scats
Results:
(**Table 20**--top 10 prey genera found)

Together, cusk eels and sea bass were 58.3% of otoliths found (neither species is commercially important)

Conclusions:
CA's probably hunt mostly at night and are opportunistic, varied feeders

Jeffries, S., 1984

Area: Columbia River estuary
Methods and Times:
Scat analysis (Feb., 1982); Gastrointestinal tract content analysis (strandings 1980-1982)
Numbers: 10-15 scats; 16 gastrointestinal tracts

Results:
(**Table 21**--prey species found (in CA's and Harbor seals; an additional 9 Steller sea lion and 50 Harbor seal gastrointestinal tracts were included in the "Stranded Marine Mammals" column)

Lampreys were frequent prey

12.5% CA tracts contained salmon remains (0% of Steller sea lion tracts contained salmon remains)

Conclusions:
CA's may be helping salmonid populations by lowering lamprey populations

Lowry, M. et al, 1990

Area: San Clemente Island, CA
Time: Sept., 1981-Sept., 1986
Method: Scat analysis
Number: 1476 scats (1309 scats had identifiable prey)
Results:
(**Table 22**--prey species found)

98.5% scats contained fish remains; 35.5% contained cephalopod remains

Northern anchovy were a major food source of CA's

6 prey species were commercially valuable: jack mackerel, northern anchovy, market squid, Pacific mackerel, Pacific whiting, and rockfish

CA's ate @115,000-295,000 million tons biomass in 1983

Conclusions: CA's feeding patterns vary seasonally; availability and abundance of prey influence CA's diet

CA's feed on schooling fishes and cephalopods and on pelagic crustaceans that drift in swarms

Lowry, M. et al, 1991

Area: San Nicholas Island, CA
Time: Summer, 1981-Fall, 1986
Method: Scat analysis (collected every 1 or 2 months at rookeries)
Number: 1232 scats (1085 scats had identifiable prey)
Results:
(**Table 23**--prey species found)

Conclusions:
CA's are plastic specialists that capitalize on seasonally abundant and accessible schooling or aggregating prey

CA's preference is for northern anchovy when available

Gamboa, D., 1991

Area: Baja CA, Mexico
Results:
11 known prey of CA's:
Bigmouth sole (Hippoglossina stomata)
Pink cusk eel (Lepophidium prorates)
Basketweave cusk eel (Ophidion scrippsae)
Serrano (Serranus aequidens)
Lumptail searobin (Prionotus stephanophrys)
Panama hake (Merluccius angustimanus)
Pacific porgy (Calamus brachysomus)
Longfin sanddab (Citharichthys xanthostigma)
Speckledfin midshipman (Porichthys myriaster)
CA lizardfish (Synodus lucioceps)
Yellowbelly lizardfish (Synodus jenkinsi)

Part B: CA Sea Lion Populations and Abundance

Mate, B., 1973

Area: OR coast
Time: 1969-1971
Results:
CA population peaks at OR rookeries were @70-80% lower in 1971 than in 1969 and 1970

Conclusions:
Male CA move into OR rookeries in Aug.

CA breed in the spring

Adult males move north in winter and south in summer; females and immature males move south in winter and north in summer

Roffe, T. and B. Mate, 1984

Area: Rogue River, OR
Time: June, 1976-Oct., 1978
Method: Surveys (at 17 sites)
Number: 5-10 monthly
Results:
CA breed in June and July

Peaks of abundance were in spring

Conclusions:
Abundance did not correspond to just a single environmental factor

Abundance peaks in the spring may be related to lamprey availability or correlate with spring steelhead and chinook migrations

Aurioles, D. et al, 1979

Area: Gulf of CA, Mexico
Time: 1969 and 1979

Results:
Population: @6,000 in 1969
@14,000 in 1979

59.6% of population is in Grandes Islas area

Pupping occurs in June and July

Roffe, T., 1980

Area: Rogue river, OR
Time: June, 1976-May, 1979
Results:
Population peaked in spring

Conclusions:
Abundance does not appear to correlate with environmental parameters

Seasonal distribution does not seem to be related to salmonid abundance

Peaks in CA population may be related to lamprey abundance

Everitt, R. et al, 1981

Area: Puget Sound, WA
Time: 1978-1979
Results:
CA are seasonal migrants that peak in winter to @300 in northern Puget Sound

Antonelis, G. et al, 1984

Area: San Miguel Island, CA
Time: 1978-1979
Results:
CA is the most abundant pinniped in coast CA waters

Antonelis, G. and C. Fiscus, 1980

Area: Total range (Mexico to southern British Columbia)
Time: Late 1970's
Method: Summary of previous studies

Results:
(**Table 11**--prey species and population (of CA, Steller sea lions, and Harbor seals))

World population: @80,000-125,000

Conclusions:
CA abundance is affected by seasonal abundance of prey species

Aurioles, D. et al, 1983

Area: Southern Baja CA
Time: Early 1980's
Results:
After breeding season (June/July), adult males migrate north to CA, OR, WA, and British Columbia

Stewart, B. and P. Yochem, 1984

Area: San Nicholas Island, CA
Time: Feb., 1980-Sept., 1982
Results:
CA are most abundant during June-July and least abundant in winter and early spring

Jeffries, S., 1984

Area: Columbia River estuary (South Jetty to Beavers Terminal)
Time: Apr., 1980-Sept., 1982
Method: Monthly, regional aerial surveys (counting and photos) and ground counts
Results:
Total range: Baja CA to British Columbia
World population: Over 100,000
Columbia River population: @200-250 (with seasonal variation)

Pupping occurs end of May-end of June

Aurioles, D. et al, 1984

Area: Bay of La Paz, Baja CA Sur, Mexico
Time: 1978-1983
Method: Censuses
Number: 49 censuses on land

Results:
Average population: @142.6 +/-37.8

Annual pup production was @40-50

Lowry, M. et al, 1990

Area: San Miguel Island, CA
Time: 1983
Results:
Population: @69,700

@5% estimated annual increase in population

Aurioles-Gamboa, D. and A. Zavala-Gonzalez, 1994

Area: Gulf of CA
Time: Summer, 1980's
Method: Censuses
Number: 29 colonies
Results:
Population: @23,256 (@31,393 with census adjustments)

Population break down:
@6.9% male adults
@5.0% male subadults
@40.7% females
@23.9% juveniles
@33.7% pups
@0.8% miscellaneous

Conclusions:
CA distribution may be affected by concentrations of prey species

SECTION III: PACIFIC HARBOR SEALS

Part A: Harbor Seal Food and Feeding Habits

Spalding, D., 1964

Area: British Columbia coast
Time: 1961 (mostly Apr.-Oct.)
Method: Stomach content analysis
Number: 126 stomachs (69 had food)
Results:
(**Table 1**--stomach contents found (in Harbors and Steller sea lions); **Table 2**--some prey species found as a percentage of total contents (in Harbors and Steller sea lions); **Table 3**--common and scientific names of prey species)

Over 50% of contents was a combination of squid, clupeids, salmon, rockfish, cod, hake, flatfish, greenling, lamprey, and smelt

A large proportion of the salmon found were found in 29 Harbors' stomachs collected near spawning creeks in Sept. and Oct.

54% of contents were a combination of herring (12%--eaten year round), salmon (30%--eaten mostly near spawning streams in fall, some in summer) eulachon, hake, whiting, flatfish, sablefish, and lingcod (all commercially valuable fish)

Conclusions:
Bottom fish and octopus are important prey

Harbors feeding patterns may be influenced by abundance of prey

Harbors in the inside waters feed mainly on squid, ratfish, and sablefish

Harbors probably eat mostly eulachon during winter, mostly octopus, rockfish, and salmon in summer, and mostly salmon in fall (1/3 of all prey eaten in fall)

Harbors may fast during pupping, which occurs in June

Harbors do not seem to follow or specially seek out salmon or herring

Pitcher, K., 1977

<u>Area</u>: AK (Prince William Sound and Copper River Delta)
<u>Times</u>: Mid 1970's (all year for PWS, May-Sept. for CRD)
<u>Method</u>: Gastrointestinal tract content analysis
<u>Numbers</u>: 151 stomachs and 105 large intestines (PWS); 45 stomachs and large intestines (CRD) (142/196 animals' gastrointestinal tracts had identifiable prey)
<u>Results</u>:
(**Table 24**--prey species found at PWS; **Table 25**--selected prey species found at PWS seasonally; **Table 26**--prey species found at CRD)

Prey found at PWS:
82.4% Fishes (47.1% Gadidae) (pollock were dominant prey)
8.6% Squid
8.0% Octopus
(Minor seasonal variation in preferred prey species)

At CRD eulachon were dominant prey and was the only species found in June and July except 1 red salmon; there were 4 species in Sept.; there was seasonal variability in prey species

AT CRD:
61% Harbors had fed on 1 species
28% Harbors had fed on 2 species
9% Harbors had fed on 3 species
3% Harbors had fed on 4 species

Johnson, M. and S. Jeffries, 1983

<u>Area</u>: WA
<u>Time</u>: 1976-1977
<u>Method</u>: Stomach content analysis
<u>Number</u>: 48 stomachs (24 had identifiable contents; 9 had unidentifiable fish remains)
<u>Results</u>:
Break down of stomach contents:

6/14 stomachs contained:	Eulachon (<u>Thaleichthys</u> <u>pacificus</u>)
	Northern anchovy (<u>Engraulis</u> <u>mordax</u>)
5/14 stomachs contained:	Ghost shrimp (<u>Callianassa</u> <u>californianus</u>)
	Sand shrimp (<u>Crago</u> sp.)
	Dungeness crab (<u>Cancer</u> <u>magister</u>)
2/14 stomachs contained:	Hagfish (<u>Polistotrema</u> <u>stouti</u>)
	Lamprey (<u>Lampetra</u> <u>tridentata</u>)
	(both of which prey on commercially valuable fish species)
1/14 stomachs contained:	Salmon (<u>Oncorhyncus</u> sp.)

3 Pacific tomcod (Microgadus proximus) and 2 hake (Merluccius productus) were identified

Conclusions:
Harbors are opportunistic feeders and their diets vary geographically

Harbors probably feed late at night or early in the morning

Pitcher, K., 1980a

Area: Gulf of AK (Yakatat Bay-Sanak Island)
Time: 1973-1978
Method: Stomach content analysis
Number: 548 stomachs (269 had food) (Harbors shot)
Results:
(**Table 27**--stomach contents found; **Table 28**--rankings of major prey species found)

Break down of stomach contents:
74.5% fish
21.5% cephalopods
4.0% decapod crustaceans

Young Harbor's stomachs contained mostly small fishes

Conclusions:
Preferred prey species varied seasonally, probably in relationship to availability

Roffe, T., 1980

Area: Rogue River, OR
Time: June, 1976-May, 1979
Methods: Visual observation of feeding at surface; Scat analysis; Gastrointestinal tract content analysis
Numbers: 107 scats (89 had identifiable prey); 13 gastrointestinal tracts (7 strandings)
Results:
(**Table 15**--prey species found in gastrointestinal tracts of stranded animals (Harbor and CA sea lion); **Table 29**--prey species observed monthly; **Table 30**--prey species found in gastrointestinal tracts; **Table 31**--prey species found in scats monthly)

81% of the 89 scats and 92% of the gastrointestinal tracts contained lamprey; lamprey occurred as prey in all months; 0% of Harbor gastrointestinal tracts contained steelhead and not lamprey and 61.5% contained lamprey and not salmonids

Break down of prey found:
56% Lamprey
4.4% Steelhaed
5.6% Salmon

Conclusions:
Harbor predation on lamprey may benefit salmonids by reducing the numbers of this parasite

Salmonids are preyed upon opportunistically not as a primary target of foraging

Roffe, T. and B. Mate, 1984

Area: Rogue River, OR
Methods and Times:
Visual observation of feeding at surface (1976-1977); Scat analysis (1976-1979); Gastrointestinal tract content analysis (1978-1979)
Numbers: 60 observations; 89 scats; 14 gastrointestinal tracts
Results:
(**Table 32**--prey observed (appears to be a copy of Table 29); **Table 33**--prey found in gastrointestinal tracts (appears to be a copy of Table 30); Refer to **Table 31** for prey found in scats)

Salmonids appeared to be more important prey for Harbors in observations, but lamprey dominated gastrointestinal tracts

Almost all Harbor gastrointestinal tracts that contained salmonids also contained lamprey, but many contained lamprey and not salmonids

Conclusions:
Harbors may consume enough lamprey, thereby reducing the affects of this parasite on salmonids, to compensate for their consumption of salmonids

Gastrointestinal analysis showed salmon are only of minor importance as Harbor prey; salmon are probably taken opportunistically

Prey availability affects feeding patterns

Brown, R., 1980

Area: Netarts Bay, OR
Time: Aug., 1977-May, 1979
Method: Visual observation of feeding at surface; Scat analysis; Mathematical estimation
Number: 149 scats (91 had identifiable prey)

Results:
(**Table 34**--fish species found; **Table 35**--frequency of fish families found)

Harbors were observed preying on chum salmon at the mouth of Whiskey Creek

2 new species of prey found: Slim sculpin and Butter sole

Sand lance is a main prey species

Conclusions:
Predation rate of chum salmon near the hatchery in 1978 was @4.8% of returning salmon, an estimated total take of @5.8% (maximum of 9.1%) (assumes same predation rates day and night)

Harbors prefer benthic and epibenthic fish

Everitt, R. et al, 1981

Area: Puget Sound, WA
Time: 1978-1979
Method: Scat analysis
Numbers: 129 scats
Results:
(**Table 36**--fish otoliths found at Gertrude Island, WA; **Table 37**--fish otoliths found at Protection Island, WA)

Conclusions:
Harbors are opportunistic feeders that vary their prey

Antonelis, G. and C. Fiscus, 1980
Area: Total range (Baja Ca-AK)
Method: Previous studies
Results:
(**Table 11**--prey species and population (Harbor, Steller sea lion, and CA sea lion))

Conclusions:
Harbors are opportunistic predators that feed on seasonally abundant prey

Pitcher, K., 1981

Area: Gulf of Alaska from Cape Suckling to Sanak Island
Time: 1980
Method: Previous study

Results:
(**Table 7**--frequency of principle prey species found (in Harbors [from 1980 study] and Steller sea lions)

Harvey, J., 1987

Area: OR
Time: 1980
Method: Previous studies; Mathematical estimates
Results:
(**Table 38**--estimates of biomass and number of fish species consumed by Harbors in OR in 1980)

Conclusions:
Harbors eat smaller fish in spring and summer and larger fish in fall and winter

In 1978, Harbors ate @66,900 tons of herring, 6,700 tons of salmon, 89,200 tons of pollock, 8,900 tons of flatfishes, 12,400 tons other gadids, and 31,200 tons other pelagic fish

In 1980, Harbors ate @5,584.9 metric tons of fish in OR; @42.5% was Leptocottus armatus (@721.4 metric tons), Clupea harrengus (@451.4 metric tons), Cymatogaster aggregata (@440.8 metric tons), Parophrys vetulus (@427.8 metric tons), and Glyptocephalus zachirus (@332.6 metric tons)

In 1980, Harbors ate @1,626.1 metric tons of flatfishes (making up @79.1% of total biomass consumed by Harbors that year)

In 1980, Harbors ate @41.8 million individual A. herapterus, 11.7 million L. armatus, and 10.4 million C. aggregata (@56.7% of total number of fish eaten that year)

In 1980, Harbors ate @112.8 million fish in OR (@658,300 of those were salmonids)

Brown, R. and B. Mate, 1983

Areas and Times:
Netarts Bay, OR: May, 1977-Nov., 1981; Tillamook Bay, OR: June, 1978-Nov., 1981
Method: Visual observation of feeding at surface (from a blind); Scat analysis at Netarts Bay (May, 1977-Aug., 1979)
Number: 150 scats (95 had identifiable prey)

Results:
(**Table 39**--fish species found in scats)

Each year, Oct.-Nov. predation by harbors on returning adult chum salmon was observed near the mouth of Whiskey Creek

Conclusions:
Harbors at Whiskey Creek ate @6.1%, 7.2%, and 1.5% of the 1978, 1979, and 1980 chum salmon returns respectively

Harbors at Netarts Bay preferred benthic and epibenthic prey species

Jeffries, S., 1984

Area: Columbia River estuary
Methods and Times:
Scat analysis (June, 1980-Apr., 1982); Gastrointestinal tract content analysis (Apr., 1980-Sept., 1982)
Numbers: 436 scats (collected in 66 visits); 50 gastrointestinal tracts (strandings)
Results:
(**Table 21**--prey found (in Harbors and CA sea lions; an additional 9 Steller sea lions and 16 CA sea lions are included in the "Stranded Marine Mammals" column))

Harbors ate much northern anchovy and eulachon in season and would go after netted salmon, but not many salmon were found in scats

12% of Harbor scats contained salmon remains

More stomachs of harbors contained salmonid remains than scats did; most salmonid remains were steelhead trout; few salmonid smolts were found

Lampreys were frequent prey

Readily available species rarely consumed by Harbors:
White sturgeon (Acipenser transmontanus)
American shad (Alosa sapidissima)
Spring Dogfish (Squalus acanthias)
Prickly sculpin (Oligocottus rimensis)
Surf smelt (Hypomesus pretiosus)
Pacific sand lance (Ammodytes hexapterus)
Most salmonid species
Common carp

Conclusions:
Stomachs may have contained more salmon than scats did because stranded Harbors may have died as a result of interaction with the gillnet fishery

Harbors may be benefiting salmonids by lowering numbers of lamprey, which parasitize salmonids

Young Harbors often prey on Crangon shrimp

Haaker, P. et al, 1984

Area: Channel Islands, CA
Time: Early 1980's
Method: Visual observations of feeding beneath the surface at night (used SCUBA gear and lights)
Results:
Harbors ate many blacksmith fish (F. Pomacentridae)

Conclusions:
Harbors are generally opportunistic feeders that eat pelagic, benthic, and anadromous fishes, mollusks, and crustaceans

Harbors engage in much foraging at night

Lowry, L. et al, 1989

Area: Gulf of AK and Bering Sea
Time: 1975-1985
Method: Previous studies
Results:
Harbors eat a variety of fish, cephalopods, and shrimps

Otter Island, April, 1979, Harbors' diets consisted of:
@63.5% Fish (@44% pollock)
@28.7% Octopus
@7.8% Other species

Nelson Lagoon, May-June, 1985, Harbors ate much fish (@5% of which was pollock; at 4 other locations, no pollock were eaten)

In the Bering Sea, 1981, Harbors ate @34,700 metric tons of pollock

21% of stomach contents of Harbors in the Gulf of AK were pollock

Perez, M., 1990

Area: Bering Sea
Time: Up to 1987
Method: Summary of previous studies
Results:
(**Table 12**--prey species)

Olesiuk, P. et al, 1990b

Area: Strait of Georgia, British Columbia
Time: Dec., 1982-Mar., 1989
Method: Scat analysis (at 58 sites)
Number: 3,000 scats (2,841 scats in Strait of Georgia, 159 scats in other regions of British Columbia) (2,917 scats had identifiable prey)
Results:
(**Table 40**--prey species found; **Table 41**--estimated annual prey consumption)

Harbor diets varied with location and season

80.8% of scats had only 1 or 2 species of prey present

Marine and anadromous fishes were 96.0% of prey found (61.1% gadoids and 58.1% clupeids)

6.1% scats had cephalopod remains and cephalopods (mainly squid) were 3.5% of prey found

Algae, barnacles, amphipods, bivalves, and gastropods were considered inadvertently collected or secondary prey

Baldridge, A. and L. Rogers, 1991

Area: CA
Time: Early 1990's
Method: Visual observation of feeding at surface
Results:
A Harbor was observed preying on a 2 meter wolf eel

Springer, A., 1992

Area: Gulf of AK
Time: Early 1990's
Method: Previous studies

Results:
Harbors consume @ 70,000 tons of pollock/yr (@21% of their diet)

Miles, A. et al, 1992

Area: Kodiak archipelago
Time: Early 1990's
Method: Previous study
Results:
Harbors eat mainly non-migratory fish and octopi

Sease, J., 1992

Area: AK
Method: Previous studies
Conclusions:
Harbors are opportunistic feeders whose diets vary geographically and seasonally

Part B: Harbor Seal Populations and Abundance

Everitt, R. and H. Braham, 1980

Area: Southeastern Bering Sea
Time: June, 1975-June, 1977
Method: Aerial surveys
Number: 5 surveys
Results:
Minimum abundance was @29,000

Roffe, T. and B. Mate, 1984

Area: Rogue River, OR
Time: June, 1976-Oct., 1978
Method: Surveys (at 17 sites)
Number: 5-10/month
Results:
Abundance increased in fall

Conclusions:
Abundance does not correspond to just a single environmental factor

Abundance may be related to fall chinook and steelhead migrations and seems to be more correlated with salmonid abundance than sea lion abundance is, but lamprey abundance probably affects Harbor abundance more than salmonid abundance does

Roffe, T., 1980

Area: Rogue River, OR
Time: June, 1976-May, 1979
Results:
Abundance was cyclic (although Harbors are not generally considered migrators), peaking in early spring just before pupping

Conclusions:
Abundance does not seem to correlate with environmental parameters

Seasonal distribution does not seem to be related to salmonid abundance

Population peaks may be related to lamprey abundance

Everitt, R. et al, 1981

Area: Puget Sound, WA
Time: 1978-1979
Results:
Population: @8,400

Brown, R., 1980

Area: OR
Time: 1972-Late 1970's
Method: Previous studies
Conclusions:
Population increased in many estuaries from 1972 to late 1970's

Antonelis, G. and C. Fiscus, 1980

Area: Total range (Isla San Martin to AK)
Time: Late 1970's
Method: Summary of previous studies
Results:
(**Table 11**--prey species and population estimates (of Harbors, CA seal lions and, Steller sea lions))

Population: @7,517 in WA, OR, CA, and Mexico combined

Brown, R. and B. Mate, 1983

Areas and Times:
Netarts Bay, OR (May, 1977-Nov., 1981); Tillamook Bay (June, 1978-Nov., 1981)
Method: Land surveys at haul out sites (at least twice/month)
Results:
Maximum abundance was reached in Nov. in Netarts Bay and in spring and summer in Tillamook Bay

Conclusions:
Population increased at Netarts Bay and stayed about the same at Tillamook Bay

A chum salmon (Oncorhynchus keta) run may influence Harbor abundance in Netarts Bay in Nov.

Harbor abundance does not correspond with salmonid abundance in Tillamook Bay; high summer abundance does coincide with abundance of northern anchovy (Engraulis mordax), surf smelt (Hypomesus pretiosus), shiner perch (Cymatogaster aggregata), Pacific herring (Clupea harengus pallasi), and English sole (Parophrys vetulus)

Abundance of Harbors at particular locations may be related to the quality of the pupping habitat

Stewart, B. and P. Yochem, 1984

Area: San Nicholas Island, CA
Time: Feb., 1980-Sept., 1982
Results:
Harbors were most abundant in late May-early June and least abundant in winter

Jeffries, S., 1984

Area: Columbia River estuary (South Jetty to Beavers Terminal)
Time: Apr., ,1980-Sept., 1982
Method: Monthly, regional aerial censuses and ground counts (counting and photos)
Results:
Total range: Baja CA-Aleutian Islands
World population: @312,000-317,000
Columbia River population: @6,000-7,000 (seasonal variation)

Pupping occurs in early Apr.-July

Harbors, CA sea lions, and Steller sea lions are the most abundant marine mammals in the Columbia River estuary; abundance may be related to abundance of prey species

Harvey, J., 1987

Area: OR
Time: 1975-1983
Conclusions:
Population increased @6-8.8%/yr from 1975-1983

Bayer, R., 1985

Area: Yaquina estuary
Time: 1977-1983
Method: Censuses

Results:
Abundance stayed about the same (summer maximum of @40-72)

Allen, S. et al, 1989

Area: Gulf of the Farallones, CA
Time: 1976-1986
Method: Surveys (at 2 haul out sites: Double Point and South Farrallon Islands)
Conclusions:
Population at Double Point doubled from 1976 to 1987

Population at South Farrallon Islands quadrupled from 1974 to 1986

Olesiuk, P. et al, 1990b

Area: Strait of Georgia, British Columbia
Time: Dec., 1982-Mar., 1989
Method: Previous studies
Results:
Population: @14,270 (seasonal variations)

Perez, M., 1990

Area: Gulf of AK
Time: Up to 1987
Method: Summary of previous studies
Conclusions:
Population is declining

Olesiuk, P. et al, 1990a

Area: British Columbia
Time: 1966-1988
Method: Aerial surveys
Conclusions:
British Columbia's Harbor population has been increasing at @12.5%/yr since 1973

Picher, K., 1990

Area: Tugidak Island, Gulf of AK
Time: Late 1980's

Results:
Tugidak Island was once the site of the largest local concentrations of Harbors in the world

Population: @20,500 in mid 1960's

Population decline @85% between 1976 and 1988 (Steller sea lion population declined as well)

Miles, A. et al, 1992

Area: Kodiak archipelago, AK
Time: Early 1990's
Results:
Population has declined

Conclusions:
Pollution may be a factor in Harbor population decline (also suggested for decline of Steller sea lions)

Springer, A., 1992

Area: Gulf of AK
Time: Early 1990's
Method: Summary of previous studies
Results:
(Figure 1--population trend (of Harbors and sea lions))

Conclusions:
Harbor rookeries in western Gulf of AK were once the largest in the world; they shrank 15% from the mid 1970's to the early 1990's; the same trends of decline were seen in the Bering Sea

Sease, J., 1992

Area: AK
Time: Early 1990's
Methods: Previous surveys and harvest records
Results:
Population: @270,000 in 1960's/early 1970's

Populations have declined in several portions of AK

SECTION IV: MARINE MAMMAL-FISHERIES INTERACTIONS

Part A: Fisheries and Affects of Steller Sea Lions, CA Sea Lions, and Harbor Seals

Spalding, D., 1964

Area: British Columbia coast
Time: 1959-1961
Method: Stomach content analysis; Mathematical estimation
Species: Salmon, herring
Conclusions:
Stellers and Harbors eat about the equivalent of 2.5% of the annual commercial catch of salmon and 4% of herring; this level is believed to be negligible in reducing salmon and herring populations

Reductions in the sea lion population from 1956-1961 did not result in corresponding increases in salmon populations

Sea lions eat more salmon in certain locations than in others

Harbors eat @2-3% of the total commercial catch of salmon; monetary loss to the fishery is @7% of total catch value of chinook salmon in the Skeena River

The total tonnage of herring eaten annually by sea lions and Harbors is @7,250 (2,400-13,250) tons, or @4% (1.0-6.2%) of the commercial catch of @200,000 tons

Sea lion and Harbor predation is not a serious factor in herring mortality

Total tonnage of salmon eaten by sea lions and Harbors is @4.0 (1.2-7.1) millions lbs annually, or @2.5% (0.8-4.7%) of the commercial catch of @148 million lbs

Fishing mortality rates of returning adult salmon rages from 50-80% depending upon species; sea lions and Harbors account for 2.5% of the fishing mortality

Briggs, K. and C. Davis, 1972

Area: Monterey Bay, CA
Time: Apr.-Sept., 1969
Method: Visual observation of fishing operations
Number: 500 hrs on 58 boats (chosen randomly)
Species: Salmon
Results:
7/244 fish hooked were lost to CA's; 7 free salmon were eaten by CA's

Conclusions:
@4.1% of hooked salmon was probably lost to CA's

Pitcher, K., 1980a

Area: Gulf of AK (Yakatat Bay to Sanak Island)
Time: 1973-1978
Species: Walleye pollock
Conclusions:
Walleye pollock are @45% by weight of Gulf of AK fish stocks

Roffe, T., 1980

Area: Rogue River, OR
Time: 1976-1979
Methods: Visual observations of feeding at surface; Scat analysis; Gastrointestinal tract content analysis
Species: Salmonids, chinook, steelhead
Conclusions:
Given the population sizes of CA's and Harbors and the proportions of their diets composed of salmonids, pinnipeds in the Rogue River do not present a danger to stocks

The combined effect of CA's and Harbors on spring chinook was removal of @less than 1% of the fish run; the sport fishery removed @14 times this amount; the effect on summer steelhead was removal of @6.4%; the sport fishery removed @2 times this amount

Roffe, T. and B. Mate, 1984

Area: Rogue River, OR
Time: 1976-1979
Species: Salmonids, chinook, steelhead
Results:
(**Table 42**--impact of pinniped feeding on salmonids)

Conclusions:
The combined effect of sea lion and seal predation on spring chinook was @less than 1.0% of the chinook population, indicating little probably impact on the fishery; the fishery harvested 14 times the amount taken by pinnipeds in 1975

Sea lions and seals ate @less than 1.0% of upriver, summer steelhead and @5-6% of downriver, immature steelhead (which are heavily fished by people); this was half the amount of the annual average taken by people from 1968-1970

"Consumption of salmon and steelhead by pinnipeds does not constitute a threat to fish stocks at the population levels and predation rates observed"

Lowry, L., 1982

Area: Bering Sea
Time: Early 1980's
Species: General, cod, herring, smelt, pollock
Conclusions:
Cod, herring, and smelt are major prey of sea lions and Harbors even when salmon are present.

Aggregate catch of groundfish in the Bering Sea by all nations, increased from @12,500 metric tons in 1954 to over @2.2 million metric tons in 1972 (% of pollock in total fishery increased from @0%-@83%)

Pinnipeds consume @2,853,000 million metric tons of finfish annually in the Bering Sea

Due to lack of documentable fish stock depletion by marine mammals, they have not been considered a factor in fish stock fluctuations (fisheries, environmental factors, and lowered trophic level interactions are considered)

Harbors and Stellers feed heavily on commercially valuable species, and the Bering Sea is a major feeding area

Frost, K. and L. Lowry, 1986

Area: Bering Sea
Time: 1975-1981
Species: Walleye pollock
Conclusions:
11 species of marine mammals, 13 species of seabirds, and ten species of fishes prey on pollock

Jeffries, S., 1984

Area: Columbia River estuary
Time: 1980-1982
Method: Stomach content analysis
Species: Salmon, chinook, coho, chum
Results:
Spring chinook gillnet fisheries in 1980, 1981, and 1982 showed between @2.1% and 4.8% of annual catch was Harbor damaged (10-33 chinook/day partially consumed by the 900-1,400 Harbors in spring)

Conclusions:
CA's do considerable damage to the salmon gillnet fishery

Spring and fall chinooks and fall coho are damaged by Harbors; chum salmon are damaged to a minor extent

Harbor damage to fisheries' fish decreases with increasing distance upriver

Harbor predation lowered dockside value of salmon by @$60,000/yr in 1980 and 1981; chinook values lowered @1% and @3.8% in 1980 and 1981 respectively and coho values lowered @3.5% and @10.8%

In 1980, @7,292, and in 1981, @7,033 salmon in gillnets were estimated damaged by Harbors

Harbors and salmonids have slight dietary overlaps

Predation may benefit salmonids genetically by selectively eliminate weaker fish

Humans affect fisheries negatively by:
Overfishing
Illegally fishing
Poor management of resources
Construction of dams
Dredging and filling streambeds
Dumping wastes
Diverting water
Manipulating genetic salmon stocks

Harvey, J., 1987

Area: OR
Time: 1975-1983
Species: General, salmonids, flatfishes
Conclusions:
In 1980, commercial fisherpeople took @12,448.7 metric tons of fishes that are prey species of Harbors; Harbors ate @3,067.9 metric tons of these species (@24.6% of amount of commercial catch)

In 1980, Harbors ate @1,321.5 metric tons of flatfishes (@22.3% of amount of commercial catch) and @533.0 metric tons of salmonids (@16.5% of amount of commercial catch)

Birds also prey on estuarine fishes

Loughlin, T. and R. Merrick, 1989

<u>Area</u>: Bering Sea and Gulf of AK
<u>Time</u>: 1976-1986
<u>Species</u>: Walleye pollock
<u>Results</u>:
Weight of individual pollock taken by fisheries generally increased each year (some pollock were as much as 3 times larger than those eaten by sea lions); many more pollock were taken in the mid 1980's than in the mid 1970's at most places (some increased take by orders of magnitude)

In 1985-1986, more large pollock were found in the sea lion feeding area at Kodiak Island than in the fishing area at Shelikof Strait

Biomass of pollock at Shelikof Strait decreased from 3.77 million tons in 1981 to 0.33 million tons in 1988; the average length and weight of 3 yr old pollock decreased from 35cm, 300gm in 1983 to less than 30cm, less than 200gm in 1988

<u>Conclusions</u>:
"The commercial fishing period is characterized by the interrelationship between man's commercial fishing activities and marine mammals and the effect that each has had on the other."

Pollock 21-46cm are the principle food of Steller's in the southeastern Bering Sea and Gulf of AK

Higher pollock weights may be the result of a good recruitment year

Size of pollock eaten by sea lions near Kodiak Island decreases as fishery sizes increase

Lowry, L. et al, 1989

<u>Area</u>: Gulf of AK
<u>Time</u>: 1976-1986
<u>Species</u>: Walleye pollock
<u>Results</u>:
(**Figure 2**--pollock eaten by Stellers and removed by fisheries; **Figure 3**--pollock eaten by Stellers and removed by fisheries as a percentage of exploitable biomass)

<u>Conclusions</u>:
Baleen whales compete with pollock for food

Baleen whales and pinnipeds feed on schooling fish, such as smelt, capelin, and herring, which compete with pollock

Demersal fishes eaten by sea lions and seals are predators of young pollock

Stellers are the major direct competitor with the pollock fishery because they remove pollocks of the same size range sought by the fishery

Sea lions eat larger pollocks than Harbors eat

Exploitable pollock biomass in the Bering Sea increased in the 1960's, peaked in the early 1970's, and declined in the mid 1970's; this decline was partly caused by a take of 9.6 million tons by the fishery from 1970-1975

Exploitable pollock biomass in the Gulf of AK increased from 1976 to a peak in 1981 and declined to 1986; much of this variation may be due to recruitment; fisheries removed over 1.1 million tones from 1981-1985

Generally, fisheries annually increased their catch of pollock from 1976-1986, but Stellers decreased pollock consumption; sea lions ate fewer and smaller pollock in the mid 1980's than before

Lowered pollock stock levels are probably the result of synergistic effects of weak age classes, excessive harvest, and sea lion predation

Sea lion predation may be having a depensatory effect on pollock stocks

Heimlich-Boran, J, 1988

Area: Pacific northwest, Canada
Time: Mid 1980's
Conclusions:
Orca prey on Harbors

Livingston, P., 1991

Area: Eastern Bering Sea
Time: 1984-1986
Method: Stomach content analysis; Mathematical analysis (estimates are probably low)
Species: Roundfish, groundfish, flatfish, pollock
Results:
(**Table 43**--estimated biomass of roundfish consumed by groundfish; **Table 44**--estimated numbers of roundfish consumed by groundfish; **Table 45**--estimated biomass of flatfish consumed by groundfish; **Table 46**--estimated numbers of flatfish consumed by groundfish)

Pollock cannibalize

Brodeur, R. and P. Livingston, 1988

Area: Eastern Bering Sea
Time: 1985-1986
Method: Shipboard scans; Stomach content analysis
Species: General, pollock
Results:
(**Table 47**--fish predation on commercially important species; **Figure 4**--diet overlap among fish)

Conclusions:
The diets of commercially important fish species overlap creating competition

Commercially important fish species are preyed upon by other fish (juvenile walleye pollock are a major prey species for several piscivorous fishes)

Stanley, W. and K. Shaffer, 1995

Area: Lower Klameth River, CA
Time: 1984-1988
Method: Visual observation (of tagging of adult migrating salmonids by the CA Dept. of Fish and Game)
Species: Salmonids
Results:
More predation by Harbors occurred on days that salmonids were seined than on other days

Conclusions:
@3.1%-5.5% of seined, released salmonids were eaten by Harbors

Bigg, M. et al, 1990

Area: Comox Harbor and Cowichan Bay, British Columbia
Time: 1989-1990
Method: Visual observation from boats and land 5PM-7PM (mostly 10AM-1PM)
Number: 342 pinniped kills of salmon witnessed
Species: Salmonids, chinook, pink, coho, chum
Results:
Seasonal abundance of Harbors was maximum in Oct. and Aug. and minimum in Nov., which coincides with salmon abundance; seasonal movements of Harbors, Stellers, and CA's into estuaries coincides with salmon migrations

Sea lions tended to feed deeper than Harbors and usually feed individually; Harbors feed shallower and often hunted cooperatively in groups of @2-4 (share catch) (Harbors are usually described as solitary hunters)

Sea lions and Harbors tended to feed mainly on the outer edges of estuaries

Conclusions:
Estimated take of total returning by Harbors at Comox Harbor in 1989:
46% Fall chinook
4% Pink salmon
8% Coho salmon
7% Chum salmon

Estimated take of total returning by Harbors at Cowichan Bay in 1989:
1% Coho salmon
1% Chum salmon

Estimated take of total returning by sea lions at Cowichan Bay, 1989:
3% Coho Salmon
3% Chum Salmon

Frost, K. et al, 1992

Area: Southeastern Bering Sea
Time: Summer, 1989-1990
Method: Visual observation of feeding at surface
Conclusions:
Orcas consume salmon (unlikely to affect fish resources), Harbors, and Stellers

Springer, A., 1992

Area: North Pacific
Time: Early 1990's
Species: Pollock, Pacific cod
Results:
(**Figure 5**--trends in numbers of pollock)

Conclusions:
The pollock fishery is the largest, single commercial fishery in the world

Pollock spawn Feb.-June (early in South, late in North)

Numbers of Pacific cod have grown considerably since the mid 1970's; cod compete with pollock for food

Seabirds, such as murres and kittiwakes, prey heavily on pollock

Pollocks often cannibalize

Primary productivity in the southeastern Bering Sea can vary 30-50% between years; temperature changes also affect primary productivity

35-42% of the total exploitable biomass of pollock was taken by fisheries in 1987; total catch nearly quadrupled through the 1970's; in 1984-1985, the stock collapsed and quotas had to be reduced

Sease, J., 1992

Area: AK
Time: Early 1990's
Method: Summary of previous studies
Species: General
Conclusions:
Estimated losses to the gillnet fishery in Copper River and Bering districts were @2.5-3.9% of catch in 1978, @1.8-3.2% in 1988, and @0.3% in 1990

Allen, M., 1990

Species: California Halibut
Conclusions:
CA Halibut (Paralichthys californicus)

Prey:	Mysids
	Northern anchovy (Engraulis mordax)
Competitors:	Speckled sanddab (Citharichthys stigmaeus)
	CA lizardfish (Synodus lucioceps)
Predators:	Thornback (Platyrhinoidis tuseriata)
	CA seal lion (Zalophus californianus)

Mate, B., 1980

Area: Northeastern Pacific (AK, British Columbia, WA, OR, CA, and HI)
Method: Summary of previous studies
Species: General

Results:

Marine mammals that affect and/or are affected by sport and commercial fisheries:
Harbor seal (Phoca vitulina)
Steller sea lion (Eumetopias jubatus)
California sea lion (Zalophus californianus)
Northern fur seal (Callorhinus ursinus)
Gray whale (Eschrichtius robustus)
Humpback whale (Megaptera novaenngliae)
Beluga whale (Delphinapterus leucas)
Pilot whale (Globicephala macrorhynchus)
Killer whale (Orcinus orca)
Bottlenose dolphin (Tursitops truncatus)
Harbor porpoise (Pocoena phocoena)
Dall porpoise (Phocoenoides dalli)

Commercial Fisheries Affected by Marine Mammals:
Salmon gillnet
Salmon troll
Japanese salmon drift net and sablefish
North Pacific halibut
Alaskan king crab
West coast hake and herring
California squid and anchovy
Long line, hand line, troll tuna, bottomfish (and others in HI)

Sport Fisheries Affected by Marine Mammals:
Salmon
Steelhead

Part B: Affects of Fisheries on Steller Sea Lions, CA Sea Lions, and Harbor Seals

Lowry, L., 1982

Area: Bering Sea
Time: Early 1980's
Method: Summary of previous studies
Species: General
Conclusions:
The Bering Sea is a major feeding area of sea lions and Harbors, and the populations of these marine mammals are declining

Jeffries, S., 1984

Area: Columbia River estuary
Time: 1980-1982
Species: Salmon
Results:
@335 Harbors were killed/yr in 1980 and 1981 incidental to the salmon gillnet fisheries (entangled and drowned or clubbed); @45 CA's were killed/yr (mostly shot)

Lowry, L. et al, 1989

Area: Bering Sea and Gulf of AK
Time: Mid 1980's
Method: Summary of previous studies
Species: Walleye pollock
Results:
Estimates of Stellers killed in pollock fishery:
1978-1981: (ave) 724/yr
1982: 1,436 in Shelikof Strait
1983: 324
1984: 355

Conclusions:
Marine mammal populations have reduced as pollock catch by fisheries has declined; declines in commercial fishes may have been a factor Harbor declines

Loughlin, T. and R. Merrick, 1989

Area: Bering Sea and Gulf of AK
Time: 1976-1986
Species: Walleye pollock

Results:
The largest decline in sea lion abundance occurred before 1976; pollock catch was also decreasing then

There were less mature (egg carrying) pollock in 1988 than in 1983

Sea lions were smaller sized in 1988 than in the 1970's

Declines in sea lion numbers at Marmot Island began soon after declines in pollock in Shelikof Strait

Conclusions:
Evidence is inconclusive as to whether or not commercial catch influences sea lion abundance

Changes in size and abundance of pollock stocks caused by variable recruitment may have influenced observed trends in sea lion numbers

Switching to alternate prey may increase the energetic cost of foraging for sea lions and increase their vulnerability to disease, storms, etc.; fishery depletion of pollock may cause such changes in predation

Springer, A., 1992

Area: Bering Sea and gulf of AK
Time: Early 1990's
Method: Summary of previous studies
Species: Walleye pollock
Results:
(**Figure 6**--trends in sea lion and Harbor numbers, and commercial pollock harvests)

Sea lion and Harbor declines began at the same time commercial pollock catch began to decline

Conclusions:
Pollock decrease stocks of alternate prey (e.g. they eat sand lance which are an alternate prey of kittiwakes)

"Accordingly, in the absence of suitable alternate prey, the overall decline in abundance of pollock in the western Bering Sea since the mid 1970's could have resulted in (a) declines in populations of birds and mammals that feed on juvenile pollock, (b) increases in populations of planktivorous seabirds that compete with pollock for zooplankton, and (c) increases in populations of piscivorous seabirds that compete with pollock for lanternfish. Alternately, if pollock biomass in the Bering Sea really did blossom beginning in the late 1960's, the steadily increasing food demand of the stock might have depleted other fish populations that were even more important prey of birds and mammals."

Sease, J., 1992

Area: AK
Time: Early 1990's
Method: Summary of previous studies
Species: General
Results:
In the mid 1970's, @700-2,800 Harbors were killed incidentally by fisheries in AK

From 1964-1972, @45,192 Harbors were harvested at 3 sites in AK (ave. @5,021/yr)

Incidental mortality of Harbors was lower in the late 1980's than in the late 1970's

In 1990, @130 Harbors were killed incidental to the salmon gillnet fishery; 4 were reported killed incidental to the groundfish trawl fishery; and 3 were reported killed in the salmon troll fishery

Conclusions:
@2,100-2,800 Harbors are harvested for subsistence in AK/yr

There is very little entanglement of Harbors in marine debris

Total Harbor kill in AK in 1990 was @2,130-3,330

SECTION V: ERROR FACTORS DESCRIBED IN THE LITERATURE

Brown, R., 1980

Estimates of fish consumption: Often assume same predation rates daily and/or seasonally

Harvey, J., 1987

Area: OR
Time: 1980
Method: Captive study of scat analysis (fed captives and tested otolith and beak recovery from feces)
Number: 3 pairs of captive Harbors (at 3 aquaria in WA and OR)
Results:
(Table 48--cephalopod beaks and fish otoliths fed to and collected from Harbors)

54% of 637 fish and 37% of 35 cephalopods fed to Harbors were in feces as otoliths or beaks

Recovery rates were greater for larger fish than smaller and better for fish with more robust otoliths

Most estimates of fish length based upon recovered otoliths were low; cephalopod length estimates were generally accurate

Generally, more than 90% of otoliths and beaks were recovered within 24 hours of ingestion

Conclusions:
Otoliths can be partially digested causing underestimates of fish length; squid beaks do not generally digest and are good indicators of prey size

Assessment of pinniped impacts on fisheries is difficult because recruitment and predation change seasonally and annually; alternate predators may affect stocks as well

Pitcher, K., 1980b

Area: Gulf of AK
Time: 1975-1978
Method: Feces analysis; Stomach content analysis (Harbors shot)
Number: 351 stomachs and fecal samples
Results:
(Table 49--major prey found in stomachs and feces)

Many more cephalopods were found in stomachs than in feces

Conclusions:
Cephalopod beaks are probably often regurgitated and so do not show up representatively often in feces; beaks may persist longer in the stomach than otoliths and other fish remains do inflating the observed numbers consumed in comparison with other organisms in stomach content analyses

Cartilagenous fish are unlikely to be detected in scats

Large fish heads are often not eaten eliminating their otoliths from the analysis, affecting determinations of prey species, sizes, and quantities consumed

Roffe, T., 1980

Visual observation: Smaller prey are probably consumed underwater causing under representation in observations

Everitt, R. et al, 1981

Scat analysis: Otoliths may underrepresent prey consumed because heads are not always eaten

Lowry, L., 1982

Due to a lack of documentable fish stock depletion by marine mammals, they have not been considered a factor in fish stock fluctuations

Brown, R. and B. Mate, 1983

Visual observation: May underestimate since not all feeding is at surface

Scat analysis: Variation in digestion rates can inflate or deflate numbers of prey found; large fish heads are not consumed as often as small heads, thereby biasing otolith analysis; some defecation occurs in water and cannot be analyzed

Antonelis, G. et al, 1984

Scat analysis: Cephalopod beaks may be under represented

Jeffries, S., 1984

Scat analysis: Selective vomiting of cephalopod beaks may cause underrepresentation of cephalopods in scats; digestion rates differ for different prey; some otoliths are not ingested

DaSilva, J. and J. Neilson, 1985

Time: Early 1980's
Method: Scat analysis of otoliths defecated by a captive Harbor fed known quantities and sizes of herring
Results:
Otoliths were only recovered from the large herring (30-35cm) and only 4% of total were recovered

Conclusions:
Otolith studies severely underestimate consumption and often bias toward larger prey sizes; they can also bias toward smaller prey sizes for prey with more easily partially digested otoliths

Lowry, L. et al, 1989

Visual observation: Prey is hard to analyze because it is hard to see all feeding

Scat and Stomach content analyses: Prey is hard to analyze because not all prey leave identifiable hard parts, and digestion rates differ

General: Time, place, and food availability may affect prey found or observed

Lowry, M. et al, 1990

Scat analysis: Amounts of prey may be underestimated; secondary prey may be present; numbers of prey may under represent importance since lower numbers may simply represent larger prey size rather than less biomass consumption

Olesiuk, P. et al, 1990b

Scat and Stomach content analyses: Cephalopod beaks may not pass as quickly as otoliths causing overrepresentation of cephalopods in stomach and underrepresentation in scats; soft bodied prey may be totally digested and go undetected

Sease, J., 1992

Scat and Stomach content analyses: Large fish heads may not be eaten eliminating their otoliths from analysis; the otoliths of cartilaginous fish and delicately boned fish may dissolve more than others; cephalopod beaks may accumulate in the stomach causing under representation in scats and over representation in stomachs

Fisherpeople may underreport incidental kills of marine mammals