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POTENTIAL FISHERY RESOURCES IN THE VICINITY OF KODIAK ISLAND, GULF OF ALASKA

(Determination of saturation biomasses of marine ecological groups using a deterministic Bulk Biomass Model)

by

T. Laevastu, K. Larson and P. Livingston

Resource Ecology Task

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POTENTIAL FISHERY RESOURCES IN THE VICINITY OF KODIAK ISLAND, GULF OF ALASKA

1. THE DATA BASE

The deterministic Bulk Biomass Model (BBM) (Laevastu and Favorite 1978a) has been applied to the marine ecosystem in the vicinity of Kodiak Island for computation of saturation biomasses of exploitable species and other ecological groups. Results presented and evaluated in this report provide a background for NWAFC and OCSEAP (Ru-551) projects as well as update some aspects of a report by Livingston (1977). The computed biomasses are also used for derivation of first guess inputs to a large, complete ecosystem model--DYNUMES III (Laevastu and Favorite 1978b, Alton, Laevastu, and Livingston 1978).

The ocean area around Kodiak Island was divided into fifteen subregions (Figure 1). The subregions 1, 2, 5, 8, 11, 12, and 13 are considered coastal ("near coast") subregions; the subregions 3, 6, 9, and 14 are slope (continental slope) subregions, and subregions 4, 7, 10, and 15 are offshore (deep water) subregions--areas of the subregions are given in Table 1.

The species and the ecological groups and their composition used in this computation are:

Herring--Pacific herring

Other pelagic (fish)--capelin, other smelts, Atka mackerel, sand lance

Squids--boreal squid species (several)

Salmon--species of Pacific salmon (this group is not fully presented in the model, due to extensive migrations of these species in and out of the region)

Rockfish--Pacific ocean perch and other Sebastes species

Gadids--cod, pollock, sablefish

Flatfish--several sole species, including halibut and turbot

Other demersal (fish)--cottids and other noncommercial demersal species

Crustaceans (C)--crustaceans of commercial value, such as king and Tanner crabs and shrimp

Benthos (f.f.)--only "fish food benthos" is considered in this model

Zooplankton--copepods and euphausids; simulation of monthly standing stocks and computation of consumption

Phytoplankton--simulation of monthly standing crop and computation of consumption

The saturation biomasses computed in this model run, are defined as biomasses which do not decrease nor increase annually (e.g., from January to January next year)--i.e., the biomass growth equals its removal by predation and mortality. Furthermore, saturation biomass computations require the use of plausible lower value for growth coefficients and plausible higher value for food requirement coefficients. Saturation biomasses can be considered also as the "carrying capacity" of the ecosystem.

The growth coefficients and total mortality coefficients (sum of old age, disease and fishing mortalities) used in the model, are given in Table 2 (predation mortality or consumption is computed within the model). The growth coefficient is assumed to have a harmonic annual change. The half-range of this annual change (first harmonic constant) is also given in Table 2. The number of marine mammals and birds is prescribed in monthly time steps and no growth and mortalities are computed for them.

Food coefficients, as used in the model, are given in Table 3. The food consumption is computed either as food required for growth plus food required for maintenance, or total food required in terms of percent body weight daily. Plausible higher values for the above coefficients were used, as deduced from Jones (1978).

Average composition of food for different species/ecological groups is given in Table 4. Different food compositions have been assigned for ecological groups other than mammals and birds for coastal, slope, and offshore regions.

Conservative estimates of marine mammals and birds, present in different subregions in four different seasons, have been obtained from various sources in the literature. These numbers were interpolated to monthly values and introduced into the program. A summary of maximum and minimum numbers of mammals in the Kodiak area is given in Table 5. No data was available on harbor seals. The number of resident fur seals was increased slightly to compensate for the omission of harbor seals. It should be further pointed out that migrating marine mammals (sea lion, fur seal) pass the Kodiak area in the spring and autumn on their way to and from the Bering Sea. Furthermore, the waters off Kodiak are considered an important feeding ground for sperm whales (180,000 in the North Pacific).

The initial first guess input of the species/ecological groups does not affect the results, but does affect the number of iterations required in the program for convergence (see Table 6).

2. SATURATION BIOMASSES

The saturation biomasses of various species/ecological groups are given in Tables 7 to 9 for different subregions, arranged by groups of subregions (coastal, slope, and offshore subregions). The numerical values are given in tons/km^2; thus, the direct comparison of "productivity" of the different subregions is possible.

The fish biomasses in the present model encompass juveniles (from the age of about 6 months) and adults (or exploitable biomass). The percentage of exploitable biomass varies from species to species; in herring the exploitable biomass is only 30% of the total biomass, in pollock 71%, and in yellowfin sole 46% of the total.

The coastal or continental shelf subregions (Table 7) have the highest finfish biomass (28 to 58 tons/km^2). The subregion 1 (Cook Inlet) has the lowest finfish biomass of the coastal subregions (28 tons/km^2); thus, excluding Cook Inlet, the finfish biomasses of the coastal subregions range from 36 to 58 tons/km^2. It can be further noticed that two "inner coastal" subregions 11 and 12 have lower biomasses of finfish (36 and 37 tons/km^2, respectively) than the "outer coastal" subregions 2, 5, 8, and 13 (46, 56, 58 and 45 tons/km^2). The finfish biomass in slope subregions ranges from 26 to 35 tons/km^2 (Table 8). The lowest finfish biomasses are in offshore regions (11 to 13 tons/km^2) (Table 9). The most abundant fish are the other pelagic fish (capelin, Atka mackerel, sand lance, etc.), followed by herring, crustaceans, and gadids.

It has been pointed out by Laevastu and Favorite (1978a) that the BBM model can be used for computation of both saturation and minimum ecosystem sutainable biomasses, by changing growth coefficients and food requirement coefficients. The effect of different growth coefficients is demonstrated in Table 10. The model is considerably more sensitive to food requirement changes than to growth coefficient changes (Livingston 1978). In general, the minimum-sustainable biomass is about 30% lower than the saturation biomass.

A summary of estimated, simulated, and/or computed plankton production, standing crop, and consumption data is presented in Tables 11 to 13, which serve for testing whether the computed biomasses can be sustained with estimated (and measured) plankton production.

The basic organic production in the Kodiak area has been assumed moderate (100 to 150 $gC/m^2/year$). This estimate is likely to be conservative. If we assume conservatively that the detritus consumed by benthos is of phytoplankton origin, we find that the utilization (consumption) of phytoplankton is about 23% (27% in coastal regions, 20% in slope, and 23% in offshore regions). This computed utilization of phytoplankton is probably an overestimate, because the basic organic production is most likely higher than assumed here, and a great part of the detritus consumed by benthos originates from zooplankton and other ecological groups as carcasses (Andersen and Ursin 1977).

Nearly nothing is known on quantitative plankton dynamics in the Gulf of Alaska. Even the available standing stock measurements are deficient, as relatively few euphausids have been caught in plankton nets, but other indirect observations indicate a great abundance of euphausids. Nothing is known about the turnover rate of zooplankton in the Gulf of Alaska, therefore, some generalized knowledge from comparable areas in the Atlantic have been used in the following considerations.

The standing stock of zooplankton is assumed to be moderately high (300 to 700 mg/m^3, or 30 to 40 $tons/km^2$, the latter depending on depth distribution). The annual turnover rate is estimated very conservatively to be 5 in Tables 11 to 13. This is an underestimate, as studies in the North Atlantic indicate that zooplankton biomass reproduces itself 2 to 7% daily (Riley 1956, Cushing 1955).

Tables 11 to 13 show that the annual zooplankton consumption by the nekton is in some coastal and slope regions slightly higher than its production, whereas in offshore regions this consumption is less than 30% of the estimated zooplankton production. The reasons for the high consumption of the zooplankton in relation to its production are manifold. First, the zooplankton production in Tables 11 to 13 is estimated to be considerably lower than its plausible value. Second, the percentual amounts of zooplankton in the diet of most species/ecological groups might be slightly overestimated (Table 4).

Two reasons for high zooplankton consumption in coastal and slope subregions in relation to local production are, however, real: First, it is caused by shoreward transport of zooplankton in deeper layers from the open ocean by the upwelling type circulation that occurs in summer. In addition, the relatively abundant zooplankton organisms on the continental shelf that obtain part of their food from the surface of the sediment (Gammarids, Mysids, and Harpacticoid Copepods) have not been considered.

In view of data in Tables 11 to 13 and the shortcomings and inaccuracies in past plankton work, discussed above, it can be concluded that the plausible plankton production can sustain the saturation biomasses of other marine ecological groups as computed in this model. Furthermore, it is apparent from the lack and uncertainty of plankton data that basic organic and plankton production cannot be used as reliable sole basis for fish and other biomass production estimates and modeling.

Four other observations can be made on the bases of Tables 7 to 9 and 11 to 13. First, the nektonic biomasses are greatly dependent upon each other (i.e., feeding upon each other) and the younger, juvenile stages provide the greatest contribution. Second, benthos on the continental shelf provides another important food link, utilizing largely detritus and carcasses (which would be remineralized in deep water in offshore areas out of reach of most fish) and producing food for the nektonic portion of the ecosystem. Third, due to high utilization of zooplankton over the continental shelf, the advection of deep ocean zooplankton contributes to the general productivity of many shelf subregions. Fourth, many pelagic fish and juveniles of semidemersal fish (e.g., pollock, hake), who depend on euphausids as food, must spend part of their life feeding in offshore locations, where euphausids are plentiful and competition for them is lower than over the shelf.

3. ECOSYSTEM INTERNAL CONSUMPTION AND TURNOVER RATES

3.1 Consumption by mammals

Consumption of different ecological groups by marine mammals and birds in the Kodiak area is summarized in Table 14. Pinnipeds are the greatest consumers of finfish, followed by toothed whales and sperm whales. Consumption by marine birds is less than 20% of the consumption by pinnipeds. The pelagic fish, gadids, and rockfish are the main ecological groups subject to heavy predation by marine mammals.

The consumption by mammals as compared to the fishery is given in Table 15. The total estimated fishery by United States and foreign vessels from the Kodiak area was 75.3×10^3 tons (the fishery statistical area is slightly larger than the model area, however), and the total consumption of finfish by marine mammals and birds was computed to be 280.7×10^3 tons. Thus, the mammals consume about four times more finfish than is taken in the fishery.

3.2 Consumption by fish

The consumption of different species/ecological groups by regions is given in Tables 7 to 9 (in tons/km^2), where biomass turnover rates have also been computed. These decrease from coast to offshore, indicating the change in rate of utilization which also reflects partly the survival rate change. The turnover rates increase slightly also from east to west.

The turnover rates in a saturation biomass ecosystem are higher than in a minimum sustainable biomass ecosystem. Crustaceans and squids, with relatively slow growth and short lifespans (shrimp), have the highest turnover rate, followed by gadids and other pelagic fish. Long-lived flatfish and rockfish have the lowest turnover rates. The turnover rate for salmon is not fully representative due to the specific life mode of these fish.

Summary of the biomasses and their consumption is given in Table 15. The quantities in this table indicate that the main forage fishes are "other pelagic fish" (i.e. capelin, sand lance, etc.) and herring, followed by crustaceans and the abundant gadids. The high consumption of fish food benthos reflects its importance as food for demersal and semidemersal fish and crustaceans. Most of the consumption of fish is from the larval and juvenile portion of the biomass (re. size dependent feeding). The predation by mammals is on larger fish and competes directly with the harvest by man.

4. SUMMARY

(1) The saturation biomasses of finfish in the vicinity of Kodiak Island range from 11 to 13 tons/km^2 in offshore (deep ocean) areas, 26 to 35 tons/km^2 on the continental slope, to 36 to 58 tons/km^2 in coastal areas (Cook Inlet has 28 tons/km^2). Minimum sustainable biomasses would be about 30% lower.

(2) The most abundant groups are "other pelagic fish" (capelin, Atka mackerel, sand lance), herring, commercially exploitable crustaceans, and gadids.

(3) The available data on plankton production and standing crops in the Gulf of Alaska is deficient indeed. It is estimated that phytoplankton utilization is in excess of 20%. Zooplankton utilization over the shelf is very high, which is most likely compensated for by horizontal and vertical advection. However, the plankton production can sustain the computed saturation biomasses.

(4) Nektonic biomasses are dependent upon each other as food sources to a large extent. The main predation occurs on juveniles and raises the possibility that year class strengths of exploitable biomasses might be largely determined by grazing on juveniles.

(5) Biomass turnover rates in saturation biomasses are high (generally from 0.7 to 1.1). The turnover rates decrease from coast to offshore.

(6) Consumption of finfish by marine mammals is about four times higher than the total (United States and foreign) fishery catch.

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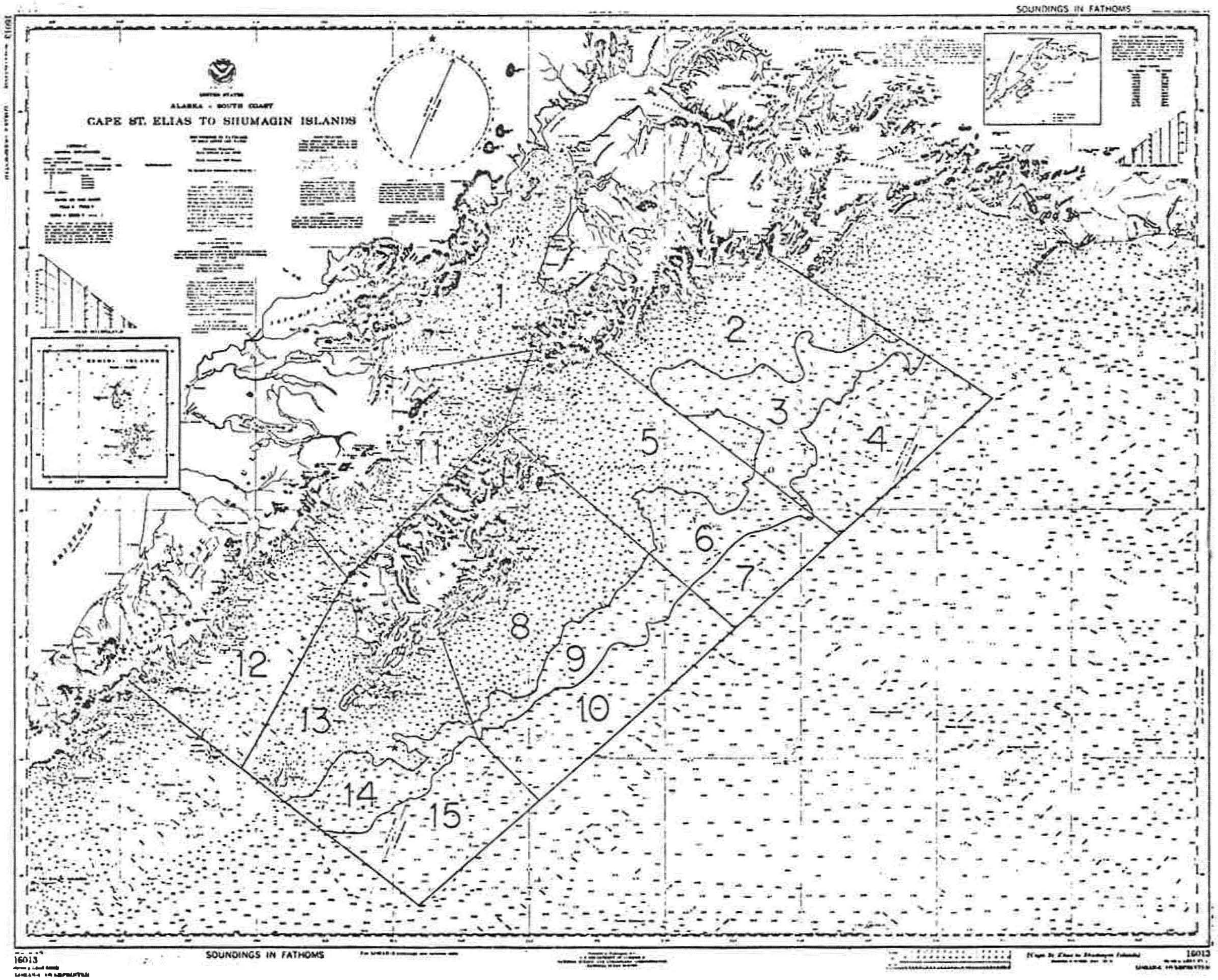

Figure 1.--Kodiak area subregions.

Table 1.--Areas of subregions and their grouping with respect to depth.

(For location of subregions see Figure 1.)

Subregion No.	Area, km^2	Subregion No.	Area, km^2
1	16,630	9	7,120
2	15,870	10	15,390
3	11,770	11	12,130
4	13,290	12	16,880
5	18,550	13	18,630
6	7,180	14	4,480
7	5,250	15	13,310
8	19,110	Total	195,590

Grouping of subregions with respect to depth and distance from the coast:

Coastal subregions	1, 2, 5, 8, 11, 12, 13
Slope subregions	3, 6, 9, 14
Offshore subregions	4, 7, 10, 15

Table 2.--Growth and mortality coefficients (monthly)

Species and/or ecological group	Growth coefficient Annual mean	Growth coefficient Half range of annual change	Mortality coefficient
Herring	0.06	0.03	0.03
Other pelagic	0.06	0.03	0.035
Squids	0.138	0.04	0.045
Salmon	0.08	0.03	0.036
Rockfish	0.05	0.025	0.0215
Gadids	0.07	0.025	0.025
Flatfish	0.05	0.02	0.0215
Other demersal	0.06	0.025	0.02
Crustaceans (c)	0.08	0.03	0.03
Benthos (f.f.)	0.10	-	0.035

Table 3.--Food coefficients.

Species and/or ecological group	Food coefficient Growth/food ratio	Maintenance, % body weight daily	Total % body weight daily
Herring	1:1.9	0.8	-
Other pelagic	1:1.9	0.8	-
Squids	1:4	-	-
Salmon	1:2	1.2	-
Rockfish	-	-	1.0
Gadids	-	-	1.2
Flatfish	-	-	1.0
Other demersal	-	-	1.1
Crustaceans (c)	-	-	1.0
Benthos (f.f.)	-	-	1.0
Fur seal	-	-	5.0
Sea lion	-	-	5.0
Baleen whales	-	-	4.0
Porpoises, dolphins	-	-	4.0
Sperm whales	-	-	4.0
Toothed whales	-	-	4.0
Birds	-	-	12.0

Table 4.--Composition of food (%): C-coastal region, S-slope, and O-offshore regions.

Herring	C	S,O
Copepods	69	59
Euphausids	12	25
Phytoplankton	14	12
Other pelagic	3	3
Herring	2	1

Squids	C	S,O
Copepods	20	23
Euphausids	35	37
Herring	25	10
Other pelagic	15	28
Gadids	4.5	2
Salmon (smolt)	0.5	

Rockfish	C	S	O
Herring	2	2.5	1
Crustaceans	7	5	2.5
Other pelagic	2	2.5	3.5
Euphausids	17	31	50
Squids	6	8	12
Benthos	15	10	8
Other demersal	10	8	4
Rockfish	2	3	3
Flatfish	3	2	1
Gadids	6	5	4
Copepods	30	23	11

Flatfish	C	S	O
Benthos	58	46.5	30
Other demersal	8	15	10
Flatfish	4	3	2
Rockfish	4	4.5	6
Euphausids	14.5	18	41.5
Herring	1.5	1	0.5
Crustaceans	6	5	4.5
Gadids	4	7	5.5

Crustaceans	C	S	O
Benthos	40	30	18
Flatfish	1.5	1	1
Rockfish	2	3	2
Euphausids	22	20	22
Crustaceans	5	6	7
Copepods	22	20	22
Phytoplankton	7	19	27
Other demersal	0.5	1	1

Other pelagic	C	S,O
Copepods	50	56
Euphausids	22	27
Phytoplankton	15	10
Other pelagic	8	5
Crustaceans	5	2

Salmon	C	S,O
Herring	25	5
Other pelagic	35	-
Squids	15	45
Euphausids	19	20
Gadids	3	30
Crustaceans	3	-

Gadids	C	S	O
Herring	2.5	3	5
Crustaceans	5	3.5	2.5
Salmon	-	0.5	2.5
Squids	6	5	4
Other pelagic	6.5	7	5
Euphausids	26	30	40
Flatfish	3.5	2.5	1.5
Rockfish	2.5	2	1
Benthos	30	23.5	11.5
Other demersal	7	7	4
Gadids	7.5	8	8
Copepods	3.5	8	15

Other demersal	C	S	O
Benthos	50	40	22
Euphausids	15	21	45
Copepods	8	10	16
Flatfish	5	5	4
Gadids	10	14	7
Other pelagic	3	4	3
Herring	3	2	1
Crustaceans	6	4	2

Benthos

(Not specified, assumed to be mainly organic detritus.)

Table 4.--Composition of food (%) (cont'd).

Food composition of mammals and birds is identical in all regions

Fur seal

Rockfish	18
Other pelagic	4
Salmon	1
Herring	5
Squids	11
Gadids	58
Others	3

Baleen whales

Euphausids	70
Copepods	14
Herring	3
Other pelagic	4
Squids	9

Sperm whales

Squids	80
Herring	7
Other pelagic	10
Salmon	1
Gadids	1
Others	1

Marine birds

Euphausids	20
Squids	10
Benthos	5
Rockfish	5
Gadids	10
Herring	35
Flatfish	5
Others	10

Sea lions

Gadids	60
Rockfish	20
Other pelagic	10
Salmon	4
Others	6

Porpoises/dolphins

Squids	20
Herring	20
Other pelagic	24
Salmon	4
Gadids	24
Others	8

Toothed whales

Squids	20
Herring	15
Other pelagic	29
Salmon	4
Gadids	24
Others	8

Table 5.--Maximum and minimum numbers of marine mammals in the Kodiak area.

Species	Maximum	Month	Minimum	Month	Annual Mean
Fur seals*	133,000	May	11,000	Aug.	50,000
Sea lions	23,900	May	3,700	Aug.	10,000
Baleen whales	44	Aug.	0	Jan.	17
Toothed whales	970	Aug.	570	Jan.	750
Porpoises, dolphins	285		285		285
Sperm whales	210	Aug.	105	Jan.	140

(Birds, 2 to 30 per km^2)

* No estimate available on harbor seals. The resident fur seal population has been increased slightly to account for harbor seals.

Table 6.--Examples of initial guess inputs and final biomasses after 40 years iterative computations.

Species/ecological group	Input (1,000 tons)			Final biomass (1,000 tons)		
	Reg. 1	Reg. 2	Reg. 3	Reg. 1	Reg. 2	Reg. 3
Herring	116	108	54	92	166	48
Rockfish	25	44	41	29	45	24
Gadids	67	97	51	77	129	76
Other pelagic	96	88	54	175	301	197
Benthos	490	477	124	579	837	325

Table 7.--Mean biomass (B) (ton/km^2), annual consumption (C) (ton/km^2), and turnover (T) in coastal subregions in Kodiak area.

Species and/or ecological group	Subregions (see Figure 1) 1			2			5			8		
	B	C	T	B	C	T	B	C	T	B	C	T
Herring	5.28	5.16	0.89	9.94	10.02	1.01	11.61	11.52	0.99	11.62	12.03	1.04
Other pelagic fish	9.90	9.61	0.97	17.44	17.94	1.03	20.33	20.79	1.02	20.16	21.16	1.05
Squids	1.76	1.83	1.04	3.52	3.67	1.04	4.10	4.19	1.02	4.20	4.49	1.07
Salmon	0.21	0.07	0.33	0.49	0.19	0.39	0.61	0.20	0.33	0.50	0.23	0.46
Rockfish	1.72	1.45	0.84	2.77	2.42	0.87	3.10	2.72	0.88	3.52	3.07	0.87
Gadids	4.63	4.21	0.91	8.07	7.52	0.93	9.15	8.40	0.92	10.15	9.52	0.94
Flatfish	2.72	2.16	0.79	4.22	3.50	0.83	4.88	4.00	0.82	5.30	4.37	0.82
Other demersal fish	3.34	2.79	0.84	5.32	4.60	0.86	6.12	5.24	0.86	6.67	5.78	0.87
Crustaceans (c)	6.13	6.83	1.08	9.83	11.55	1.17	11.34	13.34	1.18	11.80	13.87	1.18
Benthos (f.f.)	33.49	26.53	0.79	49.48	42.53	0.86	57.05	48.88	0.86	62.11	52.71	0.85
Total finfish	27.80			48.25			55.80			57.92		

Table 7.--Cont'd

Species and/or ecological group	Subregions (see Figure 1) 11			12			13					
	B	C	T	B	C	T	B	C	T	B	C	T
Herring	7.32	7.71	1.05	7.32	7.39	1.01	9.33	9.20	0.99			
Other pelagic fish	12.47	13.47	1.08	12.75	13.22	1.04	15.96	16.42	1.03			
Squids	2.54	2.89	1.14	2.45	2.70	1.10	3.20	3.36	1.05			
Salmon	0.41	0.15	0.37	0.38	0.13	0.34	0.45	0.16	0.36			
Rockfish	2.45	2.24	0.91	2.42	2.14	0.88	2.76	2.35	0.85			
Gadids	6.74	6.92	1.03	6.51	6.41	0.98	7.60	7.14	0.94			
Flatfish	3.10	2.72	0.88	3.40	2.81	0.83	4.13	3.37	0.82			
Other demersal fish	3.84	3.74	0.97	4.10	3.77	0.92	5.01	4.43	0.88			
Crustaceans (c)	7.15	8.66	1.21	7.61	8.88	1.17	9.34	10.84	1.16			
Benthos (f.f.)	36.85	32.20	0.87	40.43	33.84	0.84	48.99	40.84	0.83			
Total finfish	36.33			36.88			45.24					

Table 8.--Mean biomass (B) (ton/km^2), annual consumption (C) (ton/km^2), and turnover (T) in slope subregions in Kodiak area.

Species and/or ecological group	Subregions (see Figure 1) 3			6			9			14		
	B	C	T	B	C	T	B	C	T	B	C	T
Herring	3.86	3.75	0.97	3.03	2.86	0.94	3.12	2.92	0.94	3.13	3.12	1.00
Other pelagic fish	15.69	14.84	0.95	12.62	11.55	0.92	12.55	11.59	0.92	12.70	12.36	0.97
Squids	2.91	2.89	0.99	2.31	2.21	0.96	2.45	2.38	0.97	2.43	2.48	1.02
Salmon	0.41	0.16	0.39	0.34	0.11	0.32	0.30	0.11	0.37	0.38	0.15	0.39
Rockfish	2.07	1.68	0.81	1.57	1.22	0.78	1.48	1.14	0.77	1.83	1.46	0.80
Gadids	6.41	6.04	0.94	4.52	4.31	0.95	4.18	4.03	0.96	5.29	5.15	0.97
Flatfish	2.53	2.05	0.81	1.87	1.50	0.80	1.72	1.39	0.81	1.82	1.56	0.86
Other demersal fish	4.52	3.88	0.86	3.30	2.82	0.85	3.04	2.62	0.86	3.33	3.03	0.91
Crustaceans (c)	4.64	5.26	1.13	3.62	4.02	1.11	3.47	3.85	1.11	3.56	4.13	1.16
Benthos (f.f.	26.01	22.22	0.85	19.43	16.39	0.84	18.07	15.25	0.84	18.76	16.82	0.90
Total finfish	35.49			27.25			26.39			28.48		

Table 9.--Mean biomass (B) (ton/km^2), annual consumption (C) (ton/km^2) and turnover (T) in offshore subregions in Kodiak area.

Species and/or ecological group	Subregions (see Figure 1) 4			7			10			15		
	B	C	T	B	C	T	B	C	T	B	C	T
Herring	1.84	1.70	0.92	1.71	1.60	0.94	1.46	1.29	0.88	1.40	1.28	0.91
Other pelagic fish	7.88	7.36	0.93	7.32	6.86	0.94	6.34	5.69	0.90	6.32	5.74	0.91
Squids	1.59	1.49	0.94	1.52	1.43	0.94	1.21	1.10	0.91	1.09	1.01	0.93
Salmon	0.43	0.17	0.40	0.37	0.16	0.43	0.34	0.13	0.38	0.40	0.16	0.40
Rockfish	0.48	0.34	0.71	0.44	0.31	0.70	0.38	0.27	0.71	0.50	0.35	0.70
Gadids	1.50	1.19	0.79	1.32	1.08	0.82	1.11	0.87	0.78	1.44	1.17	0.81
Flatfish	0.49	0.33	0.67	0.42	0.29	0.69	0.39	0.26	0.67	0.42	0.30	0.71
Other demersal fish	0.76	0.55	0.72	0.65	0.48	0.74	0.59	0.42	0.71	0.66	0.50	0.76
Crustaceans (c)	1.48	1.67	1.13	1.34	1.52	1.13	1.21	1.33	1.10	1.25	1.39	1.11
Benthos (f.f.	3.91	2.93	0.75	3.39	2.57	0.76	3.14	2.30	0.73	3.38	2.58	0.76
Total finfish	13.38			12.23			10.61			11.14		

Table 10.--Effect of growth coefficient change on equilibrium biomasses

Species/ ecological group	Growth coefficient	Saturation biomass, subregion 1, 1,000 tons	Growth coefficient	Minimum sustainable biomass, subregion 1, 1,000 tons
Herring	0.06	137.5	0.115	89.5
Rockfish	0.05	34.3	0.09	26.0
Other pelagic fish	0.06	247.5	0.115	173.8
Gadids	0.07	96.7	0.105	72.2
Flatfish	0.05	55.8	0.085	43.0
Crustaceans	0.08	128.2	0.128	117.4
Benthos	0.10	538.9	0.10	549.3

Table 11.--Estimated plankton productions, standing stocks, and their consumption in coastal subregions.

Subject	Subregions 1	2	5	8	11	12	13
Annual mean phytoplankton production and mean standing crop, tons/km^2	1500 200	1500 200	1500 200	1500 200	1500 200	1500 200	1500 200
Annual mean zooplankton production and mean standing stock tons/km^2	200 40	175 35	160 32	150 30	225 45	225 45	200 40
Annual phytoplankton consumption by nekton tons/km^2	17	28	32	33	20	21	26
Annual phytoplankton consumption by zooplankton tons/km^2	264	194	171	161	241	242	207
Annual zooplankton consumption by nekton tons/km^2	99	177	206	209	129	131	165
Annual consumption of detritus by benthos ton/km^2	121	178	205	224	133	146	176

Table 12.--Estimated plankton productions, standing stock, and their consumption in slope subregions

Subject	Subregions 3	6	9	14
Annual mean phytoplankton production and mean standing crop, tons/km^2	1350 180	1350 180	1350 180	1350 180
Annual mean zooplankton production and mean standing stock tons/km^2	150 30	180 36	180 36	180 36
Annual phytoplankton consumption by nekton tons/km^2	17	14	13	14
Annual phytoplankton consumption by zooplankton tons/km^2	161	194	195	187
Annual zooplankton consumption by nekton tons/km^2	154	123	120	125
Annual consumption of detritus by benthos ton/km^2	94	70	65	68

Table 13.--Estimated plankton productions, standing stocks, and their consumption in offshore subregions.

Subject	Subregions 4	7	10	15
Annual mean phytoplankton production and mean standing crop, tons/km^2	1000 135	1000 135	1000 135	1000 135
Annual mean zooplankton production and mean standing stock tons/km^2	200 40	200 40	200 40	190 38
Annual phytoplankton consumption by nekton tons/km^2	7	6	6	6
Annual phytoplankton consumption by zooplankton tons/km^2	215	220	226	200
Annual zooplankton consumption by nekton tons/km^2	61	58	56	53
Annual consumption of detritus by benthos ton/km^2	14	12	12	12

Table 14.--Consumption of fish and other ecological groups by marine mammals in Kodiak area (in 1000 tons).

Consumed species and/or ecological groups	Consumption by						
	Pinnipeds	Toothed whales	Dolphins, porpoises	Baleen whales	Sperm whales	Marine birds	Total
Herring	4.56	21.25	0.08	0.48	11.10	16.14	104.58
Other pelagic	9.49	25.50	0.10	0.65	15.23		
Squids	10.04	21.25	0.08	1.39	11.10	4.61	48.47
Salmon	3.25	4.25	0.02	-	2.57	-	10.09
Rockfish	28.07					2.31	
Gadids	87.93	25.50	0.10	-	15.23	4.61	166.06
Flatfish	-					2.31	
Crustaceans (c)	-	-	-	-	-	2.31	2.31
Benthos (f.f.)	-	-	-	-	-		
"Others"	6.24	8.50	0.03	-	5.08	4.61	24.46
Euphausids	-	-	-	11.29		9.22	20.51
Copepods	-	-	-	(2.26)	-	-	(2.26)
Total finfish	133.3	76.5	0.3	1.13	44.13	25.37	280.46

Table 15.--Biomass (B), total ecosystem internal consumption (C), fishery (F), and consumption by marine mammals (M) in Kodiak area (in 1000 tons).

Species and/or ecological group	Biomass	Total Consumption	Fishery (1)	Consumption by mammals and birds
Herring	1,240	1,245	7.6 (7.6/0)	45.5
Other pelagic fish	2,614	2,570	-	59.0
Squids	515	531	-	48.5
Salmon	81	31	24.5 (24/0.5)	10.1
Rockfish	395	337	17.5 (1/16.5)	30.4
Gadids	1,126	1,057	16 (1/15)	133.4
Flatfish	547	458	8.4 (7.1/1.2)	2.3
Other demersal fish	741	639	1.3 (0.3/1.0)	26.8
Crustaceans (c)	1,266	1,472	93 (93/0)	
Benthos (f.f.)	6,452	5,438	-	
Total finfish	6,744	6,337	75.3	280.7

(1) Estimated catches for 1975

T - Total
(U/F) - U - U.S. catch, F - foreign catch