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Sprague, L.M.; Arnold, Jack

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9. ABSTRACT
A brief but thorough discussion of potential fish protein concentrate (FPC) and projections of its future harvest, accompanied by several illustrative tables. FPC ideally is that product resulting from modern technologies which has been transformed into a stable, dry, high amino acid quality, non-toxic, water-soluble, powdery, functional substance of varied use in formulated food products. It is likely that a marine resource will be a suitable raw material for commercial FPC. The ability of the aquatic environment to provide FPC will depend greatly on two classes of under-utilized resources. One is those resources without a market because of local food preferences, dietary habits, religious proscriptions, or competition by more valuable species. The other class are those known to occur in very substantial amounts but which now are not used frequently or at all for various technological or economic reasons. It is this latter group with which this report is more concerned. Alternative, (to marine resources) high quality protein supplies also are examined. In summary, on the lower level including present meal fisheries as potential supplies of FPC and future stocks of thread herring, mackerel, etc., potentials are about 50 million metric tons. On the immediate level which includes krill, an added 90 million metric tons for a total of about 140 million metric tons potentially are available. On the high level, perhaps part of the squid catch to a total of about 10% of production or 10 million metric tons as a maximum is available, and of the lantern fishes, quantities termed "vast" are available but under present or foreseeable harvesting and processing conditions these quantities are of little practical importance for FPC manufacture.

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Fish Protein Concentrate: The Present and Future Status of Available Oceanic Resources.

Lucian M. Sprague*
Director International Center
for Marine Resource Development and,
Professor of Oceanography
University of Rhode Island
Kingston, Rhode Island 02881

and

John Arnold
Graduate School of Oceanography
University of Rhode Island
Kingston, Rhode Island 02881

*Present address: International Bank for Reconstruction and Development, Agricultural Industries Division, Washington, D. C. 20433

In the last few years a rather large number of analytical studies have contributed very greatly to our understanding of the limits within which the growth of fishery harvest might take place.

Fishery scientists have been notably conservative in their estimates of the limits of growth, probably because of their awareness of the need for regulatory tools to limit the physical harvest of specific fisheries. Another factor may be the scientists awareness of and response to the layman's common misconception of the sea as ever fertile and infinitly rich.

For the first time we are beginning to have a factual outline of the overall productive potential of the seas[1] and consequently the potential total harvest which might be expected to result from the aquatic environment[2]. The various chapters of Gulland's recent work contributed by regionally knowledgeable authors have greatly sharpened our ability to place reasonable limits on the potential harvest of aquatic organisms. At the same time these estimates provide ample scope for informed differences of opinion about specifics. Fig. 1 shows the present status of harvest of aquatic species and Fig. 2 shows the growth of fishing power of the developed and developing economies.

Although there has been growing agreement in the last decade on the need for a framework for limiting the harvest of many marine animals there is unfortunately little reason to be optimistic that agreement on the means to achieve an adequate international management framework is within our grasp.

Clearly because of the finite limits of aquatic resources and the very rapid pace at which harvesting technology is outrunning management tools any discussion of the potentials of the aquatic regime to supply protein in any form must assume management, as at least a goal, and hope that the time frame within which the management goal is reached is short enough to prevent massive dislocations in the system.

Before proceeding further and blundering into all sorts of hidden assumptions it will be useful to define what the authors mean when we speak of FPC. In one framework FPC has been, is, and will be a major fraction of the form in which fishery products are consumed. These FPC's are called smoked and dried fish, or squid, and, kamaboku, katsuobushi, etc. However, the thrust of the present discussions, assumes, we believe, that FPC is idealy that product resulting from modern technologies which has been transformed into a stable, dry, high amino acid quality, aromatic free, nontoxic, watersoluble, powdery, functional substance of varied use in formulated food products.

Several variables profoundly influence the likelihood that a given marine resource will be a suitable raw material for commercial FPC. All the variables must combine in a way that is permissive of a final product which is competitive in cost with protein isolates or concentrates from other sources.

Others have usefully considered FPC as a highly refined and somewhat more expensive form of fish meal[3]. If one adopts this view all present and potential meal fisheries may be viewed as FPC sources given changes in the markets for animal feeds. Another way of looking at t s might be market changes brought about by changes in product technology resulting in FPC or highly refined fish meals which were capable of filling direct consumer demand as an ingredient of formulated food products for human use. Such changes in product technologies, which are quite likely, could have a major impact on the proportion of industrial fish used for FPC in the future without changes in the supply of raw material.

PRESENT AND POTENTIAL FISHERY RESOURCES

It : our hope here to set forth a reasonable statement of the ability of the aquatic environment to provide major sources of raw material for the class of products called FPC. It seems to us however that one cannot simply be satisfied with a mere shopping list consisting of a few hundred thousand tons of this and that but that one must also try to set forth the limits of the probable, and improbable.

Because one of the major emphasis of this conference is on under-utilized resources it seems appropriate to identify two classes of such resources.

First, resources which do not find a market because of local food preferences, customary dietary habits, religious proscriptions or because of competititon for hold space exerted by more valuable species. This class of underutilized fish is quite large in the aggregate amounting, we think, to perhaps as much as 5 million tons made up of a very large number of species. The majority of these are poorly recorded in national statistics and some not at all. They are thus difficult to assess with any real accuracy. Because they consist of mixed species of varied usefullness they are poorly suited for the most part to provide the raw material for a consistent high quality product such as FPC.

The other main class of resources are those which are known to occur in very substantial amounts but which are not now the subject of any major fishery for various technological or economic reasons. It is this latter group with which we wish to concern ourselves in the sections to follow.

Table 1 lists all the main groups which in our opinion are now, or are believed to be, capable of a sustainable yield in quantities sufficient to provide FPC in commercial amounts.

It should be noted that some of these groups which were on Chapman's shopping list in 1965-66 as underutilized species of great abundance have moved very rapidly to levels of full or almost full exploitation. Particularly notable in this regard are the Arctic capelin and the catches of sand eels and West African Sardinella.

Full exploitation of stocks is soon to be expected for additional sardinella stocks in the Indian Ocean along the Arabian peninsula, the thread herring in the Gulf of Mexico, and a variety of mackerel species not yet heavily exploited particularly in the Indian Ocean. Somewhat later in time, very greatly increased catches are expected for coastal squids along the west coasts of the Americas and Africa, as well as pelagic herring and anchovy like fishes in the South Western Pacific, Eastern Pacific, South Western Atlantic, and North Western Indian Ocean.

Up until about 1960 insufficient resource information, geographic remoteness, underdeveloped communications, and inadequate processing and transportation infrastructures set limits on the growth rate of industrial grade fisheries. Since then substantial improvements in the information base, a very rapid development of cruicial infrastructures, and strong demand have led to greatly expanded industrial fisheries. Many industrial fisheries which can be exploited by present harvest technologies are fully exploited. Most industrial grade fish resources available to present harvest technologies will be fully exploited by the end of this decade.

PROJECTIONS OF FISHERIES HARVEST

In Fig. 3 we have shown the present total catch of aquatic animals, this catch less the Peruvian anchovetta, Chapman's 1969 projection of total catch, and a step-wise senario of future harvest possibilities[4].

There are five distinct levels which we believe represent possible patterns for the future harvest of marine organisms. In order for substantial harvest to occur in each level certain prior conditions must be met. The first level is the present catch. The four future levels are the catch of; the thread herring, jack macherel, etc; the Antartic krill; the oceanic squid; and the lantern fishes (Mytophids).

Given some assumptions, presented later on in the discussion section, regarding relative soybean meal and fish meal production growth rates, all presently known stocks of conventional industrial grade fishes will be fully utilized by 1983/1985, or sooner if growth rates of fish meal consumption are higher than 4.5 percent. This level of total fisheries harvest will be for all aquatic species harvested by present catching technology and processed by present processing technology about 90 to 110 million metric tons.

Low Projection

A low projection for species from the total fisheries harvest for FPC would correspond to about 50 million metric tons. This is based on the assumption that no economically useful harvesting and processing technologies are developed to go beyond the harvest of present species groups plus about 20 million tons of known but underutilized thread herring, mackerel, anchovies, etc.

We expect that as the level around 100 million metric tons of total fishery harvest is reached considerable pressure for higher prices for refined fish and other protein meals will develop. If this occurs it will set the stage for the next level of marine harvest to develop. But new, and difficult to assess, limits are expected to be imposed on the remaining major fishery potentials by inadequate harvesting and/or processing technologies, conflicts over resource jurisdiction and use, and in some cases a deterioration of essential environmental quality. An additional limit may be price competition from alternative supplies of fish quality protein.

The groups expected to be constrained by these limiting factors are principally the krills, the lantern fishes and in part, the oceanic squids. One other large marine resource is as yet unexploited, the red crab of the Eastern Tropical Pacific, but in our opinion because of its potential as a direct high value food product it is unlikely to be harvested for meal in any form.

Intermediate Projection

Assuming that economically viable harvesting, and processing technologies are developed we believe the most immediately valuable and available refined meal resource will be the Antarctic invertebrate plankton commonly called krill.

If krill are brought into production, and we believe this to be very likely, the total aquatic animal harvest will rise to about 200 million metric tons. 130-150 million metric tons of the total harvest might be available for FPC manufacture providing substantial improvements in processing technology are made. Such improvements might include more efficient, lower cost, and more compact systems suitable for shipboard use.

Of the total amount of krill available between 10 and 20 percent of the harvest will probably be used as cocktail shrimp or some equivalent high value product, the remainder as meal or paste.

Krill are small shrimp-like crustaceans mostly euphasids which occur in all oceans of the world. The most important potential commercial species is Euphasia superba DANA. This species has received considerable attention in the last decade because of its great abundance and relatively large size; adults are about one to two inches long and may weight more than one gram. This species of krill occurs within the Antarctic convergence zone. Its area of greatest concentration in the Antarctic summer (Jan.-March) is shown in Fig. 4.

Estimates of the potential harvest of Antarctic krill by man range from 30-100 million metric tons[2, 5, 6]. Gulland believes that the total production could be as much as 200 million metric tons of which a substantial portion is taken by krill predators including the baleen whales, seals, birds, penguins, and other invertebrates. Man has taken a significant step in elimination of important krill predators by the drastic reduction of baleen whale stocks which lived almost exclusively on krill.

In the Antarctic summer the krill form dense schools at less than 10 meters from the surface thereby easing harvesting problems[2]. However krill are quite fragile and must be processed at once. For instance, one expedition reportedly experienced a 16% weight loss when the krill remained on the deck in 32^{o} temperature for 3 hours. Krill spoil very rapidly probably due to the action of bacterial enzymes having optimum activity at near freezing temperatures. The edible portion (1/2-1/3 of body weight) of krill have a protein content of 19% where as the inedible, shell, etc., have a 13% protein content which is mainly bound in the form of chitin[8]. Therefore, for human consumption, the shells will probably have to be removed--a process which has not been developed on a commercial scale.

Several expeditions have harvested krill in the last few years. In 1958, an expedition from the USSR trawled 100 kg. of krill in five minutes from one of the denser krill concentrations which they encountered in Antarctica[9]. In 1963, the USSR vessel Mukson harvested 70 tons of krill and used a portion of this catch to make eleven tons of meal[7]. More recently experimental development of the krill fishing by vessels of the USSR has continued producing cocktail size frozen shrimp and commercial grade meal (C. O. Chichester, personal communication). No data on the costs of operation or market success of these efforts is available to us.

High Projection

It seems almost idle to speculate on events which may give rise to the demand and economic production of fish protein concentrates at levels of total fishery harvest in excess of 200 million metric tons. But, two species groups are available for harvest, the oceanic squids and the lantern fish.

Oceanic squid are the larger high seas squids as opposed to the smaller continental shelf varieties which are caught by the New England, Japanese and other trawler fleets for sale as fresh food, fish bait, and fish meal. The oceanic squids at present are mainly caught by Japan as a specialty product. Squid have a high protein content, about 20%, which compares favorably with the fin fishes[10]. The worldwide catch is relatively small (636,000 mt) but could be expanded greatly because of their great abundance and food value. but available harvesting technologies would not be adequate for the development of a refined meal fishery because of raw material price.

Although statistical data on oceanic squid is meager, they are believed to be abundant in all oceans, particularly in areas of upwelling and other productive areas. As Clarke states "If a ship stops at night in any but high latitudes squids are attracted to the lights and are often seen in tens of hundreds within an hour." Based on the distribution of squid beaks in core samples taken from bottom sediments, there is a high correlation between squid concentrations and regions of upwelling and high productivity[10].

Gulland states that the total harvest of oceanic squid could be somewhere between a few million and 100 million metric tons[2]. Based on numerous observations similar to those of Clarke, Sprague believes Gulland's estimate to be somewhat conservative.

The umbrella jig has proven a satisfactory method for harvesting oceanic squid but this method is hardly likely to be economically feasible for the production of raw material for FPC. If the present Asian specialty market for human use were expanded to include other major markets it is unlikely that any significant fraction of the increase in catch of the squid resource would become available as raw material for FPC. We believe that changes in the market structure for these animals are more likely than the development of very low cost harvesting technologies. We believe further that only a fraction of the available 100 million metric tons of oceanic squid might be added to prior estimates, for resources available to FPC production, say at most 10% of production or at full exploitation about 10 million metric tons as a guess.

Since dried squid are already a form of FPC and since coastal squid are currently used for fish meal in small amounts, processing problems do no appear to be a limiting factor in the future use of squid as FPC raw material.

In addition to the squid the lantern fish represent a future possible resource for FPC use. Lantern fish, as described herein, includes the Myctophids, Paralepids, Cyclothone, spp, Gempylidae, Vinciguerra spp, Leptocephalae and the other small (1-5 inches long) fishes which make up the deep scattering layer. These fishes are not satisfactory from the standpoint of taste and texture for food fish, but their protein content makes them a possible source for FPC. They were used by Japan after WWII when protein was scarce[3]. The lantern fishes are thought to be very abundant with a potential harvest on the order of hundreds of millions of tons[2]. However, they would have to occur in dense concentrations, and few are known, or be concentrated by as yet undeveloped means to yield the 10 ton/day catch thought to be needed to sustain a 50-70 foot vessel[2]. Since there is little data on aggregation of these animals and economically suitable gear has not been designed, we believe that these fishes will be the last to be harvested.

Fig. 3 shows possible production levels which might be reached if lantern fish were harvested.

Projection Summary

In the lower level including present meal fisheries as potential supplies of FPC and future stocks of thread herring, mackerel, etc., potentials are about 50 million metric tons.

In the intermediate level which includes krill an added 90 million metric tons for a total of about 140 million metric tons are potentially available.

In the high level perhaps part of the squid catch to a total of about 10% of production or 10 million tons as a maximum is available and of the lantern fishes quantities deserving the sobriquet vast are available but under present or foreseeable harvesting and processing conditions these quantities are of little practical importance for FPC manufacture.

EFFECTS OF ALTERNATIVE HIGH QUALITY PROTEIN SUPPLIES

The most important alternative sources of low cost, high quality proteins are the vegetable meals. The relationship between vegetable meals rich in essential amini acids and fish meals is an important one. The price, supply, and demand for meals, particularly soybean meal, affects the demand for fish meal and its price. And the rate at which vegetable meals are placed on the market may have a profound effect on the rate at which presently underutilized marine resources are brought into production.

The most important substitute for fish meal is soybean meal. It is the best plant protein feed supplement for dairy and beef cattle, and because of its generally high quality protein profile it ranks ahead of all other common vegetable meals for feeding swine and poultry.

Soybean meal lacks methionine and vitamins and is low in lysine, phosphorous, and calcium content. Complete animal feed formulations may be achieved by adding vitamins, methionine, lysine, and minerals or by mixing soy meal and fish meal together. Because high quality fish meals contain in addition to methionine, lysine, and minerals, "unidentified growth factors," the latter may often be preferable.

The same pattern of formulation is very likely to emerge in the high quality meals designed for human consumption namely that the ultimate product will not be solely FPC or marine protein concentrate but will be a blend of high quality meals each chosen for its unique contribution to the nutritional quality, ease of use of the final product, and its contribution to the final product price.

In other words a simplistic solution to the problem of protein rich high quality meals is not likely in our opinion to be found in fish or marine protein concentrates or in any other single meal source. Since each meal has its unique advantages and disadvantages it seems approriate to combine them. A fact known, we are told, to the industry for sometime.

The recent growth rates in production and consumption of vegetable meals and fish meal show substantial increases. In the period 1955/57 through 1963/65 fish meal production increased 12 percent annually compared with a 4 percent rate of increase for all vegetable meals. In the 63/65 period annual fish meal production was about 3.3 millon tons or 8 percent of total meal production, which was about 45.5 million metric tons. By 1970 fish meal production was about 5.4 million metric tons of total meal production which has 57.6 million metric tons. Rates of growth 1963/65 to 1969/70 were about 8 percent per annum[11].

These rates of growth in fish meal production are expected by some to slow somewhat to about 4.5 percent per annum such that by 1975 about 6 million tons of fish meals are projected based on present rates of growth and present price ratios of about 1.6 to 1.7 of use of soybean meals to fish meals[12, 13, 14]. The picture presented by Alverson and Broadhead and shown in Fig. 5 illustrates the recent history of meal production[15].

The present demand for meals is generated almost entirely by animal feeding programs which are at present most highly developed in the United States, Western Europe, and centrally planned countries. Although the consumption and rates of consumption are growing rapidly in some developing countries.

In addition to soy protein considerable recent attention has been directed toward single-cell protein (SCP) grown by fermentation processes on a variety of substrates including methane, petroleum and molasses.

Although substantial plans are underway in the centrally planned countries to produce SCP supplements, their use in animal feeds or human nutrition is not yet far enough developed to determine what if any effect SCP might have on the development of fishery based protein supplies. It is, also, not possible here to assess the relative importance of urea as a cattle food supplement although according to FAO reports the use of urea may be increasingly important[16].

NEED FOR RESOURCE MANAGEMENT AND RESEARCH

With the exception of stocks in the Indian Ocean, the Southeast Atlantic, and selected areas in the South China Sea, and the Indonesian archipelago, most of the worlds table grade fisheries resources are now being harvested at or beyond their maximum sustainable yield. Many of the industrial grade species from traditional fishery areas are also being heavily exploited.

We believe that effective national and international mechanisms are needed at once to prevent serious changes in the biological composition of species available for harvest, as exemplified by the history of the California sardine fishery. Effective management mechanisms are also needed to prevent very serious economic dislocations which would follow in the not unlikely wake of additional major failures in important fisheries of which haddok, whales and sardines are examples.

If prior conditions are fullfilled leading to the major harvest of the krill, oceanic squid, and lantern fish we will be in serious trouble. These troubles will likely extend to areas beyond the scope of this paper but not your imagination. One may seriously question the wisdom of harvesting the food web of the sea so intensively as to possibly destroy the various linkages which must exist within the web[17].

For example a harvest of the krill population at levels approximating 100 million tons would almost certainly preclude the recovery of the Antarctic baleen whale populations even under conditions of a moratorium on the harvest of whale stocks. Other highly adapted species in the Antarctic which depend directly or indirectly on the krill might also be reduced or eliminated.

There is increasing evidence that species diversity per se is a measure of and necessary condition for what might be termed biological quality of life[18]. And in view of the fact that we so poorly understand the implications for human populations of changes in the global food web we believe that it would be unwise to press vigorously for the harvest of the <u>greater part</u> of the potential marine resources available for FPC manufacture prior to mechanisms for; limiting the catch at levels sufficient to sustain the fished populations as well as those other populations known to depend upon the fished populations for their livelihood; limiting economic and political conflicts in regard to the harvest of resources beyond national jurisdiction; providing sources of funds from the use of present and future resources to support resources research primarily for management purposes.

A generous estimate places the present level of living marine resources research (not including "oceanographic" research) at somewhat less than one percent of the ex-vessel value of the fisheries harvest of the oceans. It seems almost certain that increased expenditures on resources research leading to better management and sustained harvest would be more than recovered by an increase in average yields and a more stable investment climate for fisheries. Well designed systems of limited entry appear to be a necessary corollary to both the research and capital investment needed if ocean resources are to be used for the maximum benefit to man at minimum environmental degredation.

Table 1

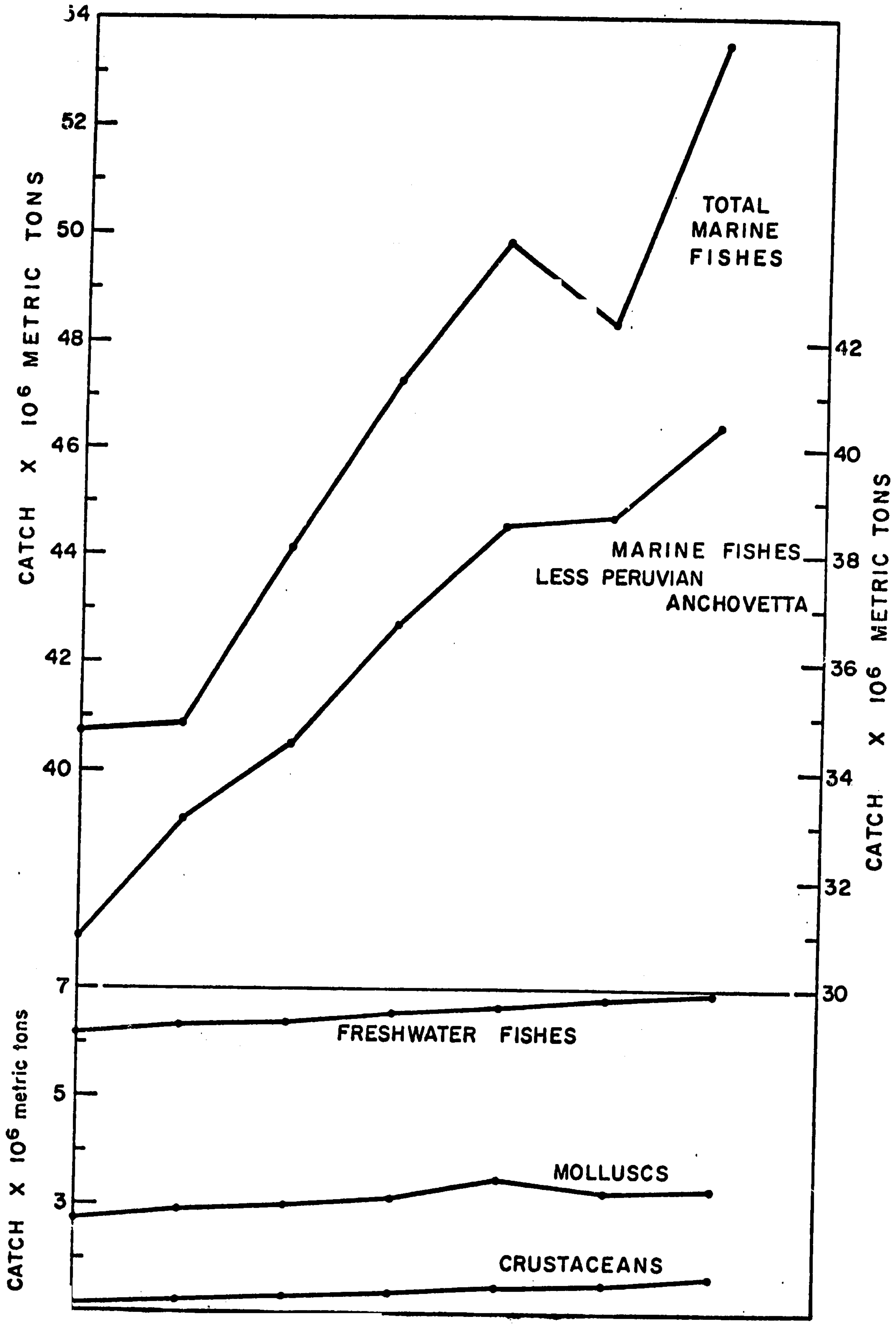
Species	65	66	67	68	69	70	Gulland[2] unless otherwise noted Potential Harvest all oceans x 10^3m	 FPC Raw Material	Remarks
Capelin	281	521	513	623	855	1515	2300	good	Nearly fully exploited on present grounds
Clupeonella	419	455	444	426	352	553	600	good	fully exploited
Hake	1085	1270	1670	1396	1256	1421	3400	poor	table grade fish
Sand eels	254	254	317	356	228	426	2400	good	
Lantern fish	0	0	0	0	0	19	100,000	?	excessive harvesting costs
Misc. small Mackerel	2724	2926	3539	3845	4055	4396	9000*	fair	moderately high harvesting costs
Herring	4600	4611	4295	3734	2885	2804	3500*	good	almost fully exploited
Sardinella	175	187	253	227	381	764	2100*	good	
Oil sardine	334	307	315	369	251	300	3500*	good	
South African Pilchard	1040	952	1105	1586	1402	672	1000	good	fully exploited
Menhaden	784	596	530	625	704	825	900*	good	fully exploited
Thread Herring	9	26	42	42	42	50	1600*	good	legal-political barriers off U.S. coasts
Anchovy not incl. Peru	1128	1155	1283	1270	1319	1366	10,000	good	legal-political off W.N. America (4 million mt.)
Peruvian Anchovetta	7681	9621	10530	11272	9709	13053	11,000	good	fully exploited

Table 1 (cont'd)

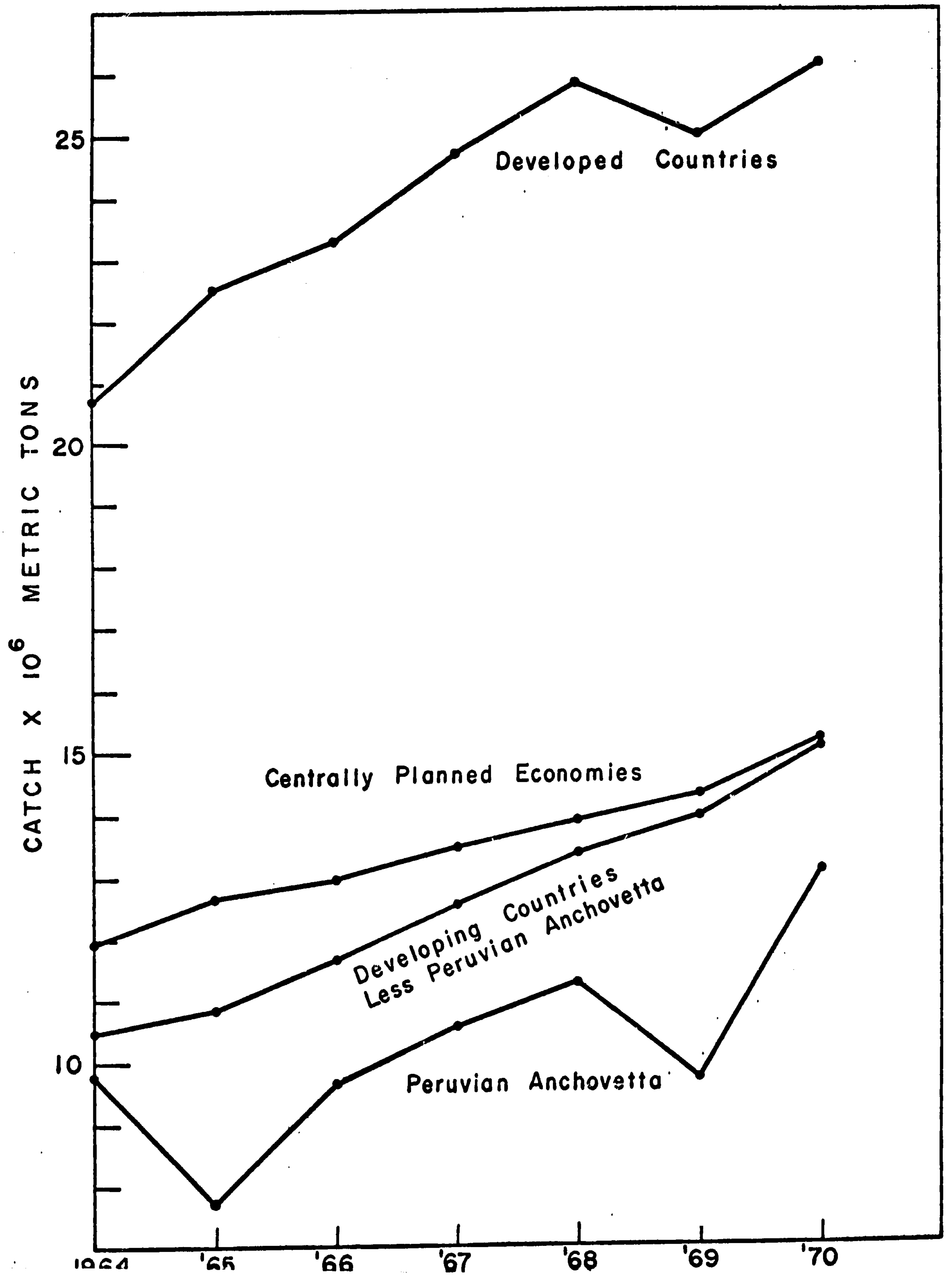
Species	65	66	67	68	69	70	Gulland[2] unless otherwise noted Potential Harvest all oceans x 10^3m	FPC Raw Material	Remarks
Misc. Herring and Sardines		Considerable local harvest					2000*	good	scattered stocks
Misc. Marine fish	7610	7850	8440	8760	9090	9580	13,000*	poor	best for animal feeds
Oceanic sharks	410	440	460	480	510	520	500*	fair	plus dog fish and others
Ocean squid	492	472	580	766	583	636	10,000	poor	harvesting costs high
Red crab							1000	poor	direct human consumption
Krill		Research catch only					50,000-100,000	good	

* our estimates source. Yearbook of Fish Stat[19]. U.S. Nat. Marine Fisheries Service, Foreign fishery leaflets and other.

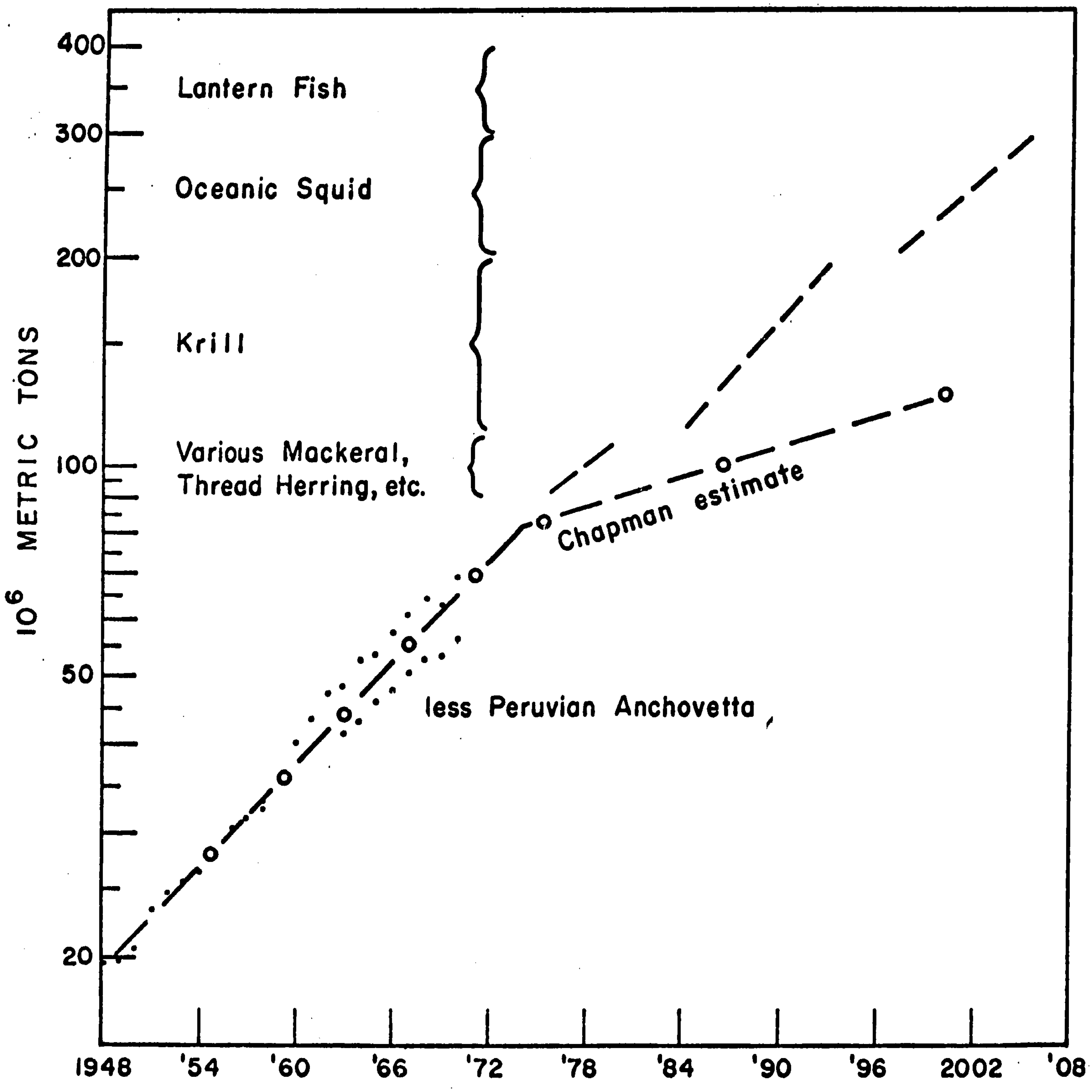
List of Figures



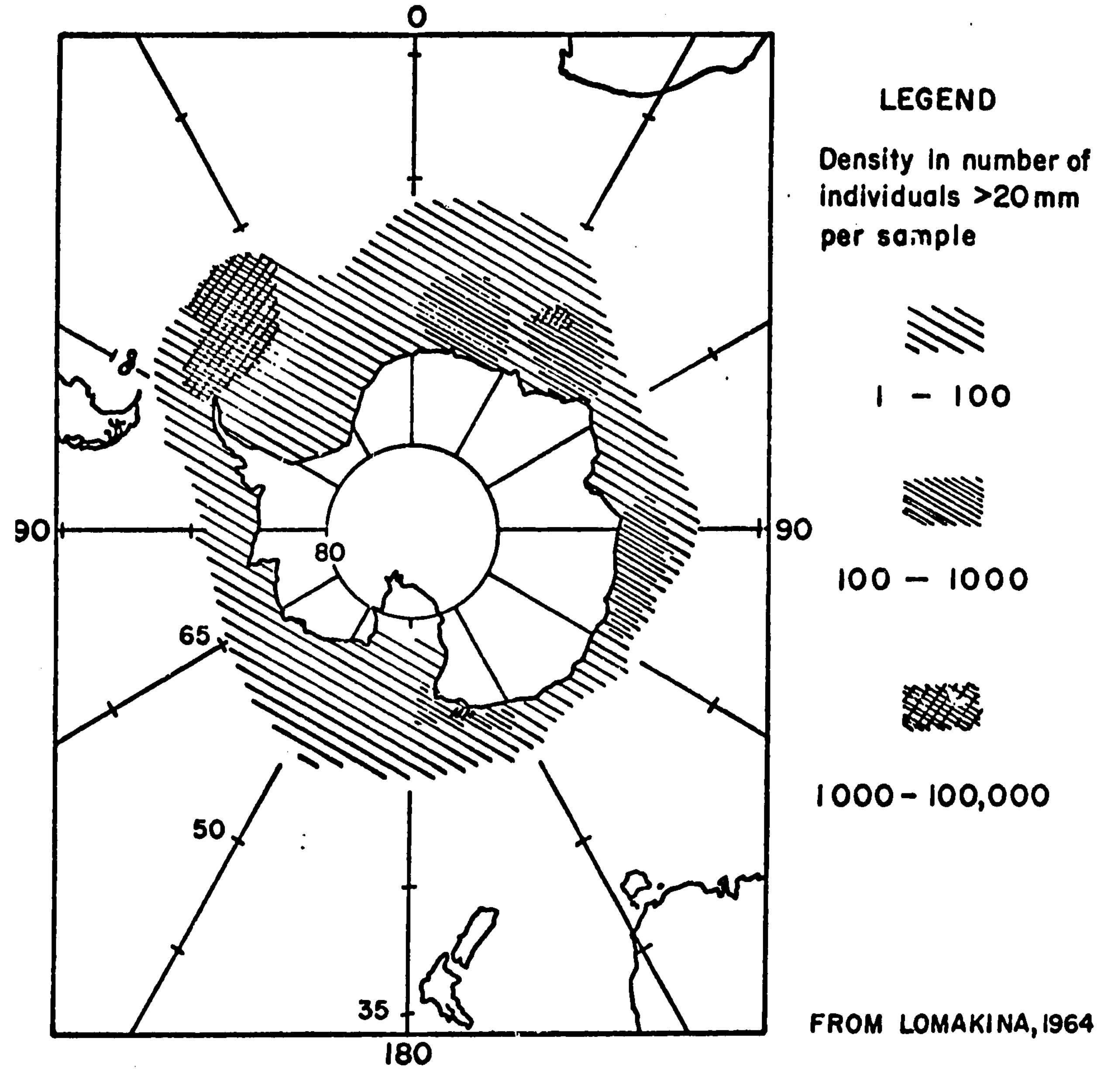
54
52
50
48
46
44
42
40
CATCH X 10⁶ METRIC TONS
TOTAL MARINE FISHES
MARINE FISHES LESS PERUVIAN ANCHOVETTA
42
40
38
36
34
32
30
CATCH X 10⁶ METRIC TONS
7
5
3
CATCH X 10⁶ metric tons
FRESHWATER FISHES
MOLLUSCS
CRUSTACEANS

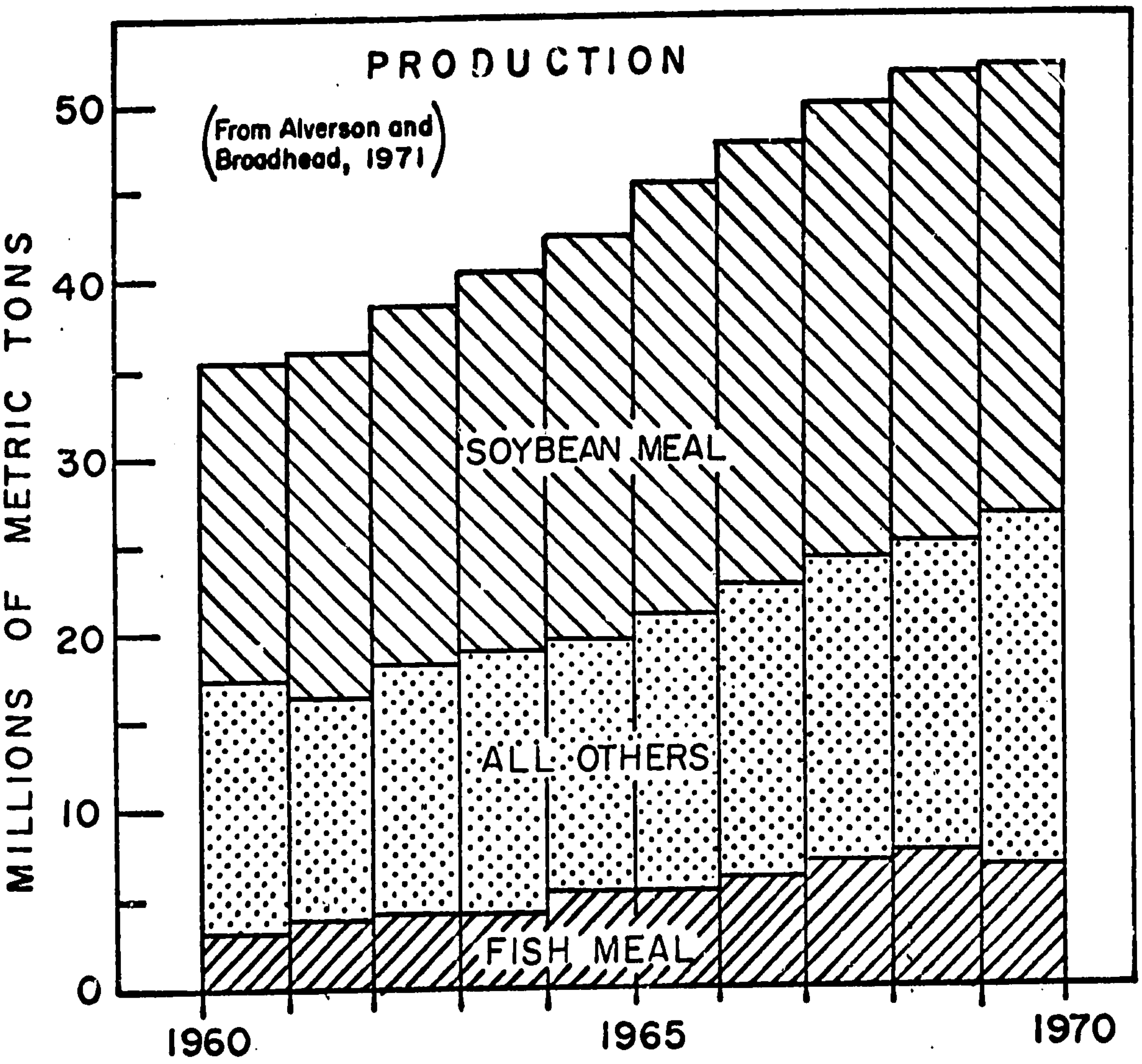


CATCH X 10^6 METRIC TONS
25
20
15
10
Developed Countries
Centrally Planned Economies
Developing Countries
Less Peruvian Anchovetta
Peruvian Anchovetta
1964
'65
'66
'67
'68
'69
'70



400
300
200
100
50
20
10^6 METRIC TONS
Lantern Fish
Oceanic Squid
Krill
Various Mackeral,
Thread Herring, etc.
Chapman estimate
less Peruvian Anchovetta
1948
'54
'60
'66
'72
'78
'84
'90
'96
2002
'08


0
90
90
80
65
50
35
180
LEGEND
Density in number of individuals >20 mm per sample
1 - 100
100 - 1000
1000 - 100,000
FROM LOMAKINA, 1964


PRODUCTION
(From Alverson and Broadhead, 1971)
SOYBEAN MEAL
ALL OTHERS
FISH MEAL
MILLIONS OF METRIC TONS
0
10
20
30
40
50
1960
1965
1970

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