Scientific Management of the World Stocks of Tunas, Billfishes, and Related Species[1]

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This paper reviews past experience in tuna research and management, and proposes guidelines for the future. The resources discussed include three major groups: the six principal market species of tunas, which are heavily exploited; the billfishes, which are in most cases heavily exploited; and the secondary market species of smaller tuna and tuna-like fishes, which are generally underexploited. A brief review of their nomenclature, biology, and fisheries is given, followed by comments on the condition of the stocks. A discussion of institutional arrangements for the scientific study and management of tuna resources is presented, and such arrangements are examined in the light of problems which might be unique to tuna and tuna-like fishes. These special problems and ways in which they might be handled are considered.

L'auteur fait le point de l'expérience acquise dans les activités de recherche et d'aménagement relatives aux thons et propose des orientations pour l'avenir. Les ressources étudiées comprennent trois groupes principaux: les six grandes espèces commerciales de thons, qui sont fortement exploitées; les voiliers, qui sont fortement exploités dans la plupart des cas; et les espèces d'intérêt commercial secondaire, à savoir les petits thons et espèces voisines, généralement sous-exploités. La première partie du document traite brièvement de leur nomenclature, de leur biologie et de leur pêche; vient ensuite une étude sur la situation des stocks. Les arrangements institutionnels conclus en vue de l'étude scientifique et de l'aménagement des ressources en thons font l'objet d'un examen; ils sont analysés en fonction des problèmes que pourraient spécifiquement poser les thons et espèces voisines. Ces problèmes spéciaux et les solutions qui pourraient leur être apportées sont examinées.

El autor reseña cuanto se ha hecho en el campo de la investigación y regulación de las poblaciones de túnidos y propone directrices para el futuro. Los recursos examinados pueden dividirse en tres grupos importantes: las seis principales especies comerciales de atún, sometidas a una explotación intensa; los peces aguja, explotados también intensamente en la mayoría de los casos; y los pequeños túnidos y otros peces semejantes, secundarios desde el punto de vista comercial y subexplotados en general. En la primera parte del trabajo se estudia brevemente su nomenclatura, biología y pesquerías, completando esta información con observaciones sobre la situación de las poblaciones. Se examinan los acuerdos entre instituciones para estudiar científicamente y regular los recursos atuneros y, se analisan estos acuerdos a la luz de algunos problemas que tal vez sean exclusivos de los túnidos y peces análogos. En la última parte del trabajo se tratan estos problemas y las posibles formas de abordarlos.

THIS paper reviews past experience in tuna research and management, and proposes guidelines for the future. Resources discussed include three major groups: the six principal market species of tunas, which are heavily exploited; the billfishes, which are in most cases heavily exploited; and the secondary market species of smaller tunas and tuna-like fishes, which are generally underexploited.

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The Animals and Their Exploitation

NOMENCLATURE AND BIOLOGY

The tuna and tuna-like fishes are grouped for economic reasons, because the majority of them are taken during the same fishing operations. In this paper three family groups will be discussed, the scombrids, xiphiids, and istiophorids. True tunas and tuna-like species, of which there are about 40, are usually classed in the Scombridae. Within this group are the six major tuna species (the principal market species) that comprise about 75% of world catches of tuna and tuna-like fishes. Also included with the scombrids are other species of tuna-like fishes. In an economic sense these are secondary market species, and their combined catch represents about 20% of the

world catch of tuna and tuna-like fishes. The various species of billfishes, which include all members of the families Xiphiidae and Istiophoridae, are generally grouped as tuna-like from an economic point of view because the majority of them are taken by tuna fishing vessels while fishing for tuna, but in a biological sense they are not closely related to tunas. The billfishes account for about 5% of the world catch of tunas and tuna-like species. Table 1 lists species within taxonomic groups. The scombrids are divided into principal and secondary market groups. Somes species which are taken in limited amounts, such as *Thunnus atlanticus*, *T. tonggol*, *Allothunnus fallai*, and *Orcynopsis unicolor*, are not included. The mackerels *Scomber* and *Rastrelliger* are omitted.

Tunas and billfishes are highly specialized, fast-growing, very mobile organisms that spend their entire life on the high seas. They are generally encountered throughout all of the major temperate and tropical oceans of the world, primarily between 35°N and 30°S.

The six principal market species of tuna are classified, on the basis of geographical distribution, as either temperate or tropical, the latter including yellowfin, skipjack, and bigeye. Two of these, the yellowfin and bigeye, grow to large sizes (over 100 kg) and generally are short-lived, less than 5 years. Though skipjack are similar in many respects to the other two tropical species, individuals rarely attain a size greater than 15 kg.

The temperate species, albacore and bluefin, grow more slowly but live longer. There are often 5–15 age-groups in these fisheries at a time, whereas the fisheries for tropical tunas are supported by only 2–5 age-groups.

The secondary market species are both tropical and temperate, and like the major species have high metabolic rates and grow rapidly. Most do not attain large sizes, however, being generally less than 35 kg.

Most billfishes are found in tropical waters, but swordfish occur in highest concentrations in subtropical and temperate waters, and in many instances in commercial concentrations in waters of less than 15 C.

Most tuna and tuna-like species are highly mobile and in many instances undertake extensive migrations. In the Pacific Ocean the northern bluefin and albacore migrate between the nearshore waters off Mexico and the United States of America and those off the coast of Japan. In the Atlantic the bluefin travel between the Bay of Biscay and Mediterranean and the waters of the Gulf Stream off Canada and the United States of America. Albacore likely migrate as widely in the Atlantic as do bluefin. In the Pacific Ocean, skipjack undertake extensive migrations, travelling at least between the coastal waters of the eastern Pacific and the central Pacific. Yellowfin and bigeye tunas do not appear to be so highly migratory, apparently remaining within a couple of thousand kilometers of where they were born.

Southern bluefin tuna, found only in the southern hemisphere, migrate from spawning areas around the continent of Australia to the Atlantic, Pacific, and Indian oceans. Information on movements of the secondary market species is scanty, but these do not appear to be as migratory as do larger tunas. Billfishes, on the other hand, are quite migratory; some species of marlin and swordfish migrate several thousand kilometers.

Methods of Harvesting and Forms of Utilization

Fisheries for tunas date back to prehistory. Harpoons, traps, and trolling gear are still used, but the major share of tuna today is captured by three more recent methods. The longline captures the largest share of tuna and tuna-like species. Three countries account for nearly all longline fishing, in order of importance, Japan, the

Table 1. Scientific, English, French, Japanese, and Spanish names of tunas and tuna-like species discussed in this report.

	English	French	Japanese	Spanish
Scombrids				
Principal Market Species				
Katsuwonus pelamis	skipjack	bonite à ventre rayé	katsuo	barrilete
Thunnus albacares	yellowfin tuna	albacore	kihada	atún aleta amarilla o rabil
Thunnus alalunga	albacore	germon	binnaga	albacora
Thunnus obesus	bigeye tuna	thon obèse	mebachi	atún ojo grande o patudo
Thunnus maccoyii	southern bluefin tuna	–	minamimaguro	atún del sur
Thunnus thynnus	northern bluefin tuna	thon rouge	kuromaguro	atún aleta azul
Secondary Market Species				
Sarda spp.	bonito	bonite à dos rayé	hagatsuo	bonito
Scomberomorus spp.	Spanish mackerel	thazard	sawara	sierra
Auxis spp.	frigate mackerel	auxide	sodagatsuo	melva
Euthynnus spp.	black skipjack	thonine	yaito	barrilete negro
Istiophorids				
Istiophorus platypterus	sailfish	voilier	bashokajiki	pez vela
Makaira spp. and *Tetrapturus* spp.	marlin	makaire	kajiki	pez aguja
Xiphiids				
Xiphias gladius	swordfish	espadon	mekajiki	pez espada

Republic of China, and the Republic of Korea. Next, in terms of landed weight of tuna, is use of live-bait to attract the schools of tuna. Third is the purse seine. This is vastly superior to other methods in terms of catch per unit of effort and is rapidly replacing bait fishing as the most important surface tuna fishing technique. Trolling with lures and with fishing traps, harpoons, and gillnets account for a large share of the catch of the secondary species, as well as a smaller share of the primary market species.

Tuna fisheries were not developed significantly until after the first world war and were not substantial until after the second world war. Fishermen of the United States of America fishing from Californian ports developed the live-bait tuna fishery in the eastern Pacific about 1915, and by 1945 they were fishing throughout the tropical waters as far south as Ecuador. During the same period the Japanese live-bait tuna fishery in the western Pacific expanded operations from near the Japanese mainland, eventually to include the entire Caroline Islands. Fishermen of France and Spain first began capturing tuna in the Bay of Biscay in significant quantities in the 1940s and shortly thereafter in waters off West Africa.

Minor fisheries for some billfish species have existed for a long time. Striped marlin and swordfish, particularly, have been harvested commercially in waters off California and Mexico since about 1915, and off Peru and Ecuador by subsistence fishermen long before that. In the Atlantic and Mediterranean, billfish have been captured for years in traps, but there were no substantial commercial fisheries until after 1950 when Japanese vessels began taking large quantities.

Tunas and billfishes are utilized in many forms. Of the scombrids, the majority are canned. The next most significant share is consumed in Japan as raw fish "sashimi," and in the third form as "katasuobushi," which is cured and dried. Of the billfishes, little is canned. Prior to 1960 most were eaten fresh but from 1960 to 1966 a large share of the catch was used in the manufacture of fish sausage and fish ham by Japan. Since 1966 the trend in Japan has been to consume the meat of billfish as sashimi; this can be attributed to the advancement in freezing techniques. This new market for billfishes has increased both the price and demand on a world scale.

Distribution of the Catch

Prior to the second world war the total production of the six principal market species of tuna never exceeded 300,000 metric tons/year. This began to increase rapidly after the war and by 1952 exceeded 450,000 metric tons. The catch then increased steadily until about 1961 when it levelled off at about 900,000 metric tons, and it fluctuated about that level until 1965. The catch increased slightly during 1965 and 1966 and by 1967 amounted to approximately 1,100,000 metric tons, and has remained at that level (Fig. 1).

On the basis of current available data I have attempted to improve the catch statistical data of the principal market species for 1971. A total catch of 1,212,500 metric tons is estimated, higher than the 1,071,000 metric tons in the preliminary FAO statistics (Table 2). These data are shown with similar information for secondary market species and the billfishes (Fig. 2).

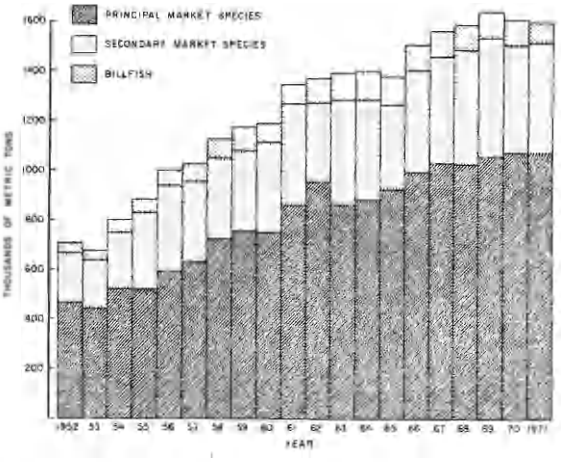

Fig. 1. Total catch of tunas and tuna-like species, as compiled by FAO, grouped within these categories of economic importance, for years 1952–71.

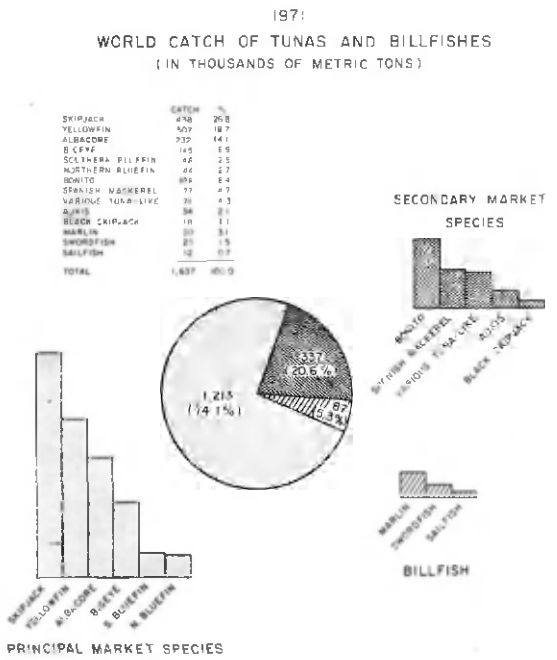

Fig. 2. The 1971 world catch of tunas and tuna-like species.

Of the principal market species, skipjack tuna represents 36.1% of the catch; yellowfin, 25.3%; albacore, 19.1%; bigeye, 12.0%; southern bluefin, 3.9%; and northern bluefin, 3.6%. These species represent 74.1% of the total catch of tunas and tuna-like fishes. The secondary

species and billfishes represent 20.6% and 5.3%, respectively. Shares of the catch and species composition for each ocean are given (Fig. 3) for the principal species. Species composition for all species and all oceans combined is given in Table 3.

Because tuna and tuna-like fishes are so widespread, occurring off the coastlines of nearly all nations bordering tropical and temperate waters, the number of nations which engage in tuna fishing activities is large. During 1971 about 40 nations reported capturing tuna, but most

TABLE 2. Estimates of 1971 catches, in thousands of metric tons and in percentage (in parentheses) of the total catch, of the six market species of tunas, by oceans.

	Atlantic catch	Indian catch	Pacific catch	All oceans catch
		A. Author's estimates		
Skipjack	81.9(18.7)	38.9(8.9)	317.0(72.4)	437.8
Yellowfin	71.9(23.5)	50.7(16.5)	184.0(60.0)	306.6
Albacore	77.1(33.3)	13.4(5.8)	141.0(60.9)	231.5
Bigeye	39.5(27.2)	31.3(21.6)	74.3(51.2)	145.1
Northern bluefin	19.5(44.5)	0 (–)	24.3(55.5)	43.8
Southern bluefin	5.2(10.9)	28.5(59.8)	14.0(29.4)	47.7
Total	295.1(24.3)	162.8(13.4)	754.6(62.2)	1212.5
		B. From FAO preliminary statistics		
Skipjack	36.0(10.9)	0 (–)	294.0(89.1)	330.0
Yellowfin	78.0(26.3)	37.0(12.5)	181.0(61.1)	296.0
Albacore	77.0(35.0)	13.0(5.9)	131.0(59.5)	220.0
Bigeye	31.0(25.0)	29.0(23.4)	64.0(51.6)	124.0
Northern bluefin	33.0(57.9)	0 (–)	24.0(42.1)	57.0
Southern bluefin	4.0(9.1)	28.0(63.6)	12.0(27.3)	44.0
Total	259.0(24.0)	107.0(10.0)	706.0(66.0)	1071.0

TABLE 3. Estimated global catch of tunas and percentage of total catches for the year 1971, in thousands of metric tons.

			Percentage	
Group	Species	Catch	Of principal species	Of all species
Principal market species	Skipjack	437.8	36.1	26.8
	Yellowfin	306.6	25.3	18.7
	Albacore	231.5	19.1	14.1
	Bigeye	145.1	12.0	8.9
	Southern bluefin	47.7	3.9	2.9
	Northern bluefin	43.8	3.6	2.7
	Subtotal	1212.5		74.1
Secondary market species	Bonito	137.6		8.4
	Spanish mackerel	76.8		4.7
	Various tuna-like	70.5		4.3
	Auxis	34.2		2.1
	Black skipjack	18.3		1.1
	Subtotal	337.4		20.6
Billfish	Marlin	50.0		3.1
	Sailfish	12.0		0.7
	Swordfish	24.9		1.5
	Subtotal	86.9		5.3
Total		1636.8		

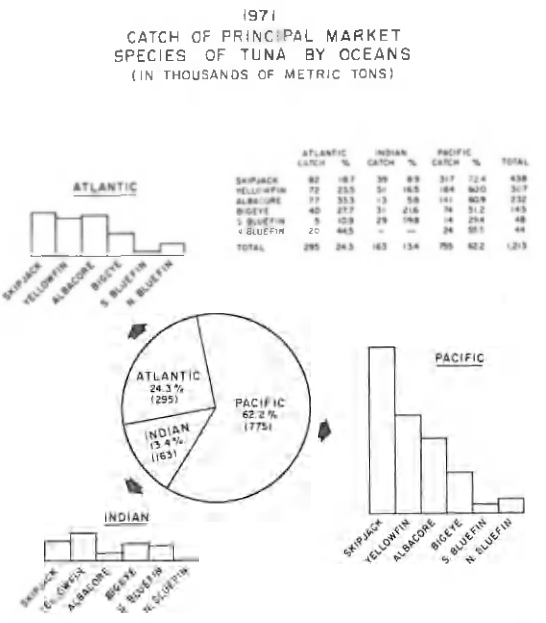

FIG. 3. The 1971 world catch of the principal market species of tuna by oceans.

of them catch small amounts (<1.0%). Six nations account for nearly 83% of the catch of principal market species, Japan and the United States of America accounting for nearly 60%; the other 34 nations catch the remainder.

Country	Principal market species Catch (thousands metric tons)	% of total
Japan	468.0	38.6
USA	238.6	19.7
Rep. of China	101.9	8.4
Rep. of Korea	73.8	6.1
France	71.6	5.9
Spain	49.8	4.1
Subtotal	1003.7	82.8
Others	208.8	17.2
Total	1212.5	100.0

MARKETING THE CATCHES

The two countries that catch the majority of the principal species of tuna consume the major share (Broadhead 1971). In 1969 Japan and the United States of America utilized about 75% of the world catch, or slightly more than their combined catch; Japan catches about 40% and uses 30%, while the United States catches about 20% and uses about 45%. During 1972, consumption of tuna by the United States will probably increase 20%. The nations of western Europe consume about 18% of the catch, the remaining 7% being distributed throughout the world.

Tuna has a world market, being consumed in most countries and shipped through most of the major ports of the world. It is priced roughly at the same level throughout the world. The total value of the 1971 catch of the principal market species in terms of equivalent United States dockside prices was more than $550 million (US).

TONNAGE CAPACITY OF THE INTERNATIONAL FLEET

To obtain some idea of the potential demand for raw tuna, and to evaluate whether such increased production is feasible, Joseph (1972b) examined recent trends in fleet size and growth. He reasoned that if fleet growth could be extrapolated it should be possible to predict production. Of course this reasoning would assume no biological constraint on production, and such an assumption is unrealistic. The discussion which follows is taken from the above paper.

Estimates of fleet size for the years 1958 through 1971 (Fig. 4) represent longliners, baitboats, purse seiners, trollers, and jigboats of approximately 20 nations, and together these account for more than 90% of the world catch of the principal market species of tunas. They should, therefore, provide an accurate index of trends in the fishery. During 1958 the international fleet had a total capacity of about 300,000 gross metric tons. An additional 100,000 tons were added in 1964 by Korea and China. Fleet capacity reached more than 700,000 tons by 1972.

In the early years, the annual catch of tuna (Fig. 4, from FAO statistics) increased more rapidly than fleet size, but in subsequent years decreased. The ratio of catch per gross metric ton declined 2.50 tons in 1958 to 1.48 tons in 1971. In terms of vessel production this catch per gross metric ton does not represent the entire catch. Many vessels fish other species in addition to tunas; in fact, billfishes are often the principal species sought by the longline fleet. The statistics of catch per gross metric ton should be indicative of trends, however, since the six species discussed in this report consistently comprise about 65% of the total catch of all tuna and tuna-like fish taken by the international fleet as reported by FAO.

Total fleet growth has been extrapolated (unconnected dots, Fig. 4). If catches of tuna remain as in 1970 and 1971, then with the projected fleet expansion the catch per gross metric ton should drop substantially (unconnected open circles). By 1974, assuming current catch levels, the catch per gross metric ton would dip to 1.30 tons, about half that prior to 1960. To maintain the 1970–71 level through 1974 the catch would have to increase about 20% (unconnected X's, Fig. 4), an additional 250,000 metric tons.

Status of the Stocks

Production of tuna from the world's oceans has increased substantially during the past 25 years. From 1950 to 1961 it nearly doubled, and from 1961 to 1967 it increased by about 15%. Consumption in the United States of America alone has nearly doubled every decade since 1920 (Chapman 1967). The demand is expected to continue to increase not only there but throughout the world. The important question is whether the resources of tuna are capable of filling this demand.

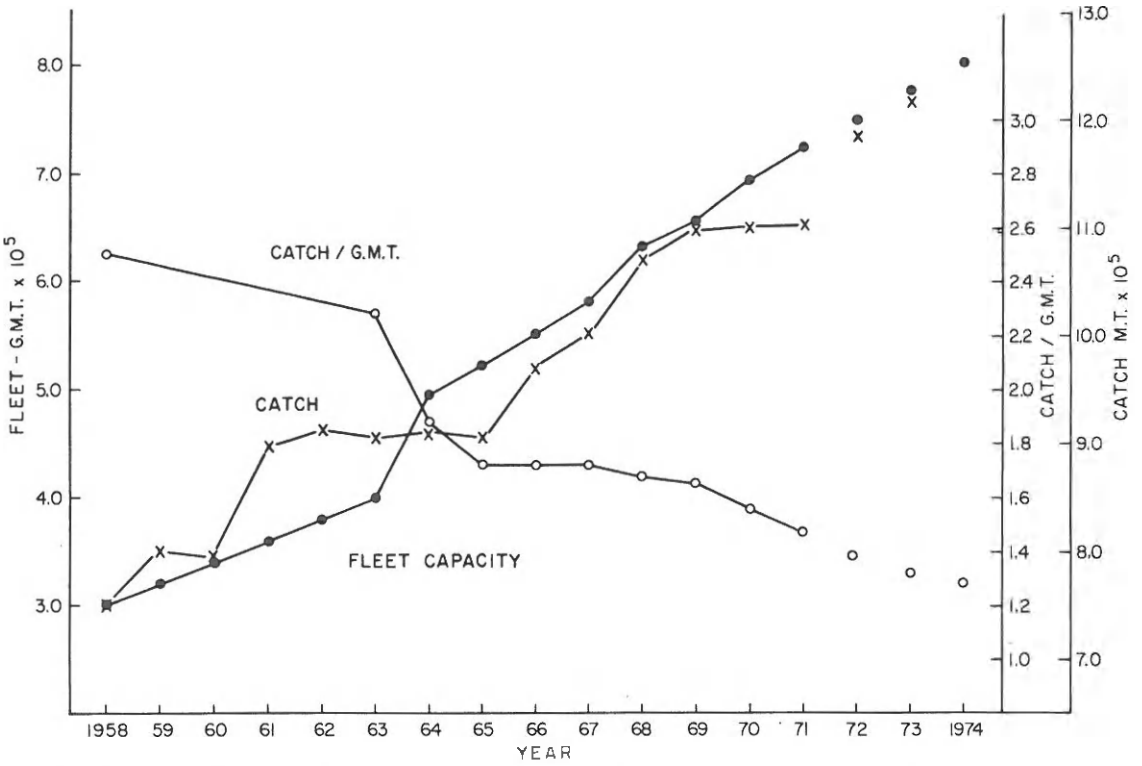

FIG. 4. Recent world trends in fleet capacity, catch, and catch per gross metric ton of capacity, for the principal market species of tuna, 1958–71, with extrapolations through 1974.

It does not appear that production can be increased at the rate of the great expansion of the 1950s as the catch has remained rather constant since 1967 in the face of increased fleet growth. Of great importance is whether we can expect any growth, or whether production of the principal species may be reduced due to overexploitation.

The most complete discussion of this question is that presented by experts convened by FAO in 1968 (FAO 1968), and a subsequent group convened in 1969 (FAO 1969), and reviewed by Joseph (1972a, b). In summary, the information suggests that most of the principal market species of tuna are nearly or fully exploited. Yellowfin, albacore, and bigeye tuna appear to be nearly fully exploited, and increased effort on these species will result in at best small increased catches and even in decreased catches. Northern bluefin tuna in the Pacific Ocean are probably fully exploited, and in the Atlantic Ocean are possibly overexploited. Albacore tuna appear to be fully exploited in all three oceans and increased production is not likely. Southern bluefin tuna has been heavily exploited recently and catches have declined by about 30%. The Japanese, who catch the major share of this species, have initiated self-imposed regulations in this fishery. Skipjack tuna, the largest component (36.1%), is taken in large quantities in the three oceans. Judging from biological data, this species appears to be underexploited throughout most of its range; thus present production might be substantially increased. A possible exception to this is in the western Pacific, where Japanese studies have suggested the catch may be approaching its upper sustainable limit.

For the secondary market species few assessments of the stocks have been made. Gulland (1972) has commented briefly on some, concluding that for bonito (40% of the catch), catches are probably nearing the upper sustainable limit, although limited expansion of effort is possible. For the other species effort can probably be increased substantially, and catches should increase. Gulland estimates that in the eastern Pacific alone the catches of frigate mackerel may be increased to 200,000 tons. Judging from the widespread distribution of this species, the world potential must be considerably higher. Another important secondary species which can probably be increased substantially is black skipjack. Research is urgently needed on these species to evaluate their potential. However, it should be emphasized that the demands for tuna stated by Chapman refer to the six principal market species and not the secondary species. In most countries the latter cannot be labelled tuna.

Little research has been done on the dynamics of billfish stocks. Fishing effort by longline gear, the main method, has been increasing during the last few years, but catches have remained rather steady. Gulland (1972) has suggested that they are probably fully exploited and increased production is not likely. For some species in certain areas

overexploitation has apparently occurred (Tibbo and Sreedharan 1972).

Present International Arrangements for the Scientific Management of Tuna

Several international organizations are concerned with management and there are two whose sole function is to provide guidance for establishment of controls on exploitation.

Inter-American Tropical Tuna Commission (IATTC)

The IATTC was established by convention between Costa Rica and the United States of America in 1949. It is an open-ended convention in which any state may join whose nationals participate in the fisheries covered by the convention, providing acceptance is given by all members. Five countries, Panama, Ecuador, Mexico, Canada, and Japan joined subsequently. Ecuador withdrew in August 1968. The convention waters are referred to as the eastern Pacific Ocean but are undefined in terms of longitude and latitude. The species of fish covered by the convention are yellowfin tuna, skipjack tuna, baitfishes used to capture tuna, and other tuna and tuna-like fishes captured by tuna vessels in the eastern Pacific Ocean.

The IATTC consists of national sections, each comprising one to four commissioners appointed by the member governments. All decisions, resolutions, recommendations, and other official actions of the Commission must be by unanimous vote of all High Contracting Parties. A Chairman and Secretary are elected at annual meetings, which are held at least once each year. A Director of Investigations is responsible for appointment and direction of scientific and technical staff. Of paramount importance among duties of the IATTC is responsibility to make recommendations, on the basis of scientific investigations, for action by the High Contracting Parties to keep the stocks of fishes at levels of abundance permitting the maximum catch on a sustained basis.

The Commission initiated its research program in 1950. The staff set about collecting historical records of catch and nominal fishing effort for the fishery, and established a system of logbook information with which catches and nominal effort could be monitored on a semi-current basis. Such data formed the basis of studies on the dynamics of the fishery; they were supplemented by the staff's intensive studies on the biology and ecology of the major tuna species of the eastern Pacific Ocean.

On the basis of these studies, estimates were made of the sustainable yield of yellowfin prior to overexploitation. (For skipjack tuna, the other species which was studied extensively, analysis indicated that it was not fully exploited.) As fishing effort increased in the eastern Pacific Ocean, overfishing of yellowfin occurred in the early 1960s. Catch quotas were recommended but these were not implemented until 1966. The fishery for yellowfin tuna has been under management since that time. The management program of the IATTC has been reviewed in detail by Joseph (1970, 1973). In summary, the program is based on a general catch quota, to be taken on a first-come-first-served basis. The quota is established each year, and applies only to the Yellowfin Regulatory Area (CYRA), established on the basis of information concerning stock structure available in 1961.

Since 1966 the fishery in the eastern Pacific has changed remarkably and the management program has also changed in an attempt to be responsive. The fleet has increased nearly three times since 1966. Competition has increased sharply and the open season for yellowfin fishing has decreased from about 10 months to less than 3. As competition increased, a portion of the overall quota has been allocated to meet the needs of countries with fleets having special economic problems. Catch quotas in the CYRA have been increased experimentally, since the fishery is expanding geographically and is fishing on a larger portion of the population than it had previously. A major problem of the Commission is related to distribution of the catch. All fleets are growing rapidly, but the fleet of one nation (the United States of America) comprises about 75% of available capacity and captures nearly 85% of the catch from the CYRA. Developing nations maintain that under the present management system their tuna fisheries cannot develop, and there are strong pressures for increased special allocations. As these allocations are established there is beginning to be a shift of flag vessels from the nations with large fleets to the nations with small fleets. Each nation with vessels fishing in the CYRA is responsible for establishing and enforcing its own tuna regulations based on the recommendations of the IATTC. As vessels relocate in other countries the number of nations involved increases, along with problems of implementation and enforcement.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

A convention for the establishment of the International Commission for the Conservation of Atlantic Tunas (ICCAT) was signed in Rio de Janeiro in 1966. Seven ratifications were necessary to bring the convention into force, and these were obtained in 1969. The convention waters comprise all waters of the Atlantic Ocean, including the adjacent seas. The Commission is responsible for the study of populations of tuna and tuna-like fishes (the Scombriformes with the exception of the families Trichiuridae and Gempylidae and the genus *Scomber*) and such other species of fishes exploited in tuna fishing in the convention area as are not under investigation by another international organization.

The convention is open for signature by any member of the United Nations or any of its Specialized Agencies. At present there are 13 members; Spain, France, Brazil, Canada, USA, Japan, Morocco, Portugal, Republic of South Africa, Ghana, Republic of Korea, Senegal, and the Ivory Coast.

Each of the contracting parties is represented in the Commission by not more than three delegates, who may be assisted by experts and advisers. Decisions of the Commission are made by a majority of the contracting parties, and two-thirds of the contracting parties constitute a quorum. Regular meetings are provided for once every 2 years.

The convention of ICCAT provides for research to be accomplished through: (1) technical and scientific services of official agencies of the contracting parties and their sub-

divisions. (2) available services and information of any public or private institution, organization, or individual, (3) independent research (within limits of its budget) not accomplished under (1) and (2). ICCAT may establish panels on the basis of species, groups of species, or geographical areas. The Commission has established four panels: (1) tropical tunas, yellowfin and skipjack; (2) temperate tunas (north), bluefin and albacore in the northern hemisphere; (3) temperate tunas (south), bluefin and albacore in the southern hemisphere; (4) other species, bigeye, bonito, billfish, and others. Such panels are responsible for monitoring populations of fish under its purview and collection of information to do so, and for proposing to the Commission, on the basis of scientific evidence, recommendations for joint action by the contracting parties. On the basis of scientific evidence the Commission may make recommendations to the contracting parties, designed to maintain populations at levels which will permit the maximum sustainable catch.

The ICCAT has chosen not to exercise its option to conduct independent scientific research. It has only a minimal staff, which includes an Executive Secretary, an Assistant Executive Secretary, and a small number of supporting administrative and clerical assistants. A Standing Committee on Research and Statistics (SCRS) has been established to recommend and guide research to be conducted by scientific organizations of its member governments. The SCRS has a number of subcommittees and working groups, comprised of scientists of its members and outside experts, to examine special scientific problems. To date the SCRS has been concerned primarily with mechanisms for the collection of catch and effort statistics for the major tuna fisheries of the Atlantic, and with assessment of stocks of yellowfin and bluefin tuna in that ocean. A major constraint on assessment of the stocks has been lack of data on catch and fishing effort.

During the 1972 Meeting a minimum size limit of 3.2 Kg was recommended for yellowfin tuna, but decisions on the need for minimum size limits on bluefin and catch quotas on yellowfin were not made.

Indian Ocean Fishery Commission (IOFC)

Two additional international organizations concerned with research, development, and management of all species of fish within their geographical area of competence include tunas in their considerations. The structure of these organizations is different from the two tuna commissions in that they are established within the framework of the FAO.

The Indian Ocean Fishery Commission (IOFC) was established by the Council of FAO under Article VI-1 of the FAO Constitution on the recommendation of FAO's Committee on Fisheries (COFI). Membership is open to all Member Nations and associate members of the FAO. There are now 28 members. The IOFC's geographical area of responsibility is the Indian Ocean and adjacent seas, excluding the antarctic area. The species of living marine resources with which it is concerned are not limited.

The objectives of IOFC are: 1) to promote, assist, and coordinate national programs over the entire field of fishery development and conservation; 2) to promote research and development activities in the area through international sources, and in particular international aid programs; 3) to examine management problems, with particular reference (because of the need to take urgent action) to those relating to the management of offshore resources.

The Commission elects a Chairman and up to six Vice-Chairmen at the end of each biennial session, but is not structured to support a research staff of its own. To accomplish its tasks it may establish subsidiary bodies as well as call upon outside expertise. With reference to problems of conservation in the Indian Ocean the IOFC has established a Committee on Management charged with recommending, on the basis of scientific evidence, measures to prevent overfishing. This Committee has a working party on stock assessment, in relation to immediate problems of management in the Indian Ocean, which has confined its activities to tuna. On two occasions it has examined data in order to assess the impact of fishing on the stocks of Indian Ocean tuna. Though they were able to make preliminary assessments, meaningful analysis was impossible without much improved statistical data. The major recommendations of this group have been for the collection of catch statistical information.

Indo-Pacific Fisheries Council (IPFC)

The Indo-Pacific Fisheries Council (IPFC) was formed in 1948 within the framework of the FAO under the provision of Article XIV of the FAO Constitution. Its membership is open to all members and associate members of FAO, and such nonmembers as are members of the United Nations. Its area of concern includes the marine and fresh waters of the Indo-Pacific region; the species with which it is concerned are undefined.

The terms of reference of the IPFC are broad and include: (1) to formulate technical aspects of problems of development and encourage proper utilization of living aquatic resources; (2) to coordinate and encourage research and dissemination of results therefrom; (3) to recommend and undertake development projects within its member nations; (4) to propose and adopt measures to bring about standardization of scientific equipment, techniques, and nomenclature.

A Chairman and Vice-Chairman are elected at each regular session of the IPFC but no provision is made for a research or technical staff. The IPFC has established a committee on tuna management in the Indo-Pacific region, but at present it is concerned with the western Pacific. Little has been accomplished by IPFC with regard to the assessment of tuna within its region.

Other Arrangements

Species of highly migratory animals which spend only a portion of their life within the territorial waters of a coastal state cannot be managed by the coastal state alone because controls applied to such resources when in territorial waters do not apply when the fish are on the high seas. The most effective means for managing resources which range over vast ocean areas has been through international conventions. Though many of these have been ineffectual, they provide the only examples of moderately successful high seas management programs in

existence (Chapman 1970; Lagarde 1972). During the last two decades a large number of fisheries commissions and international organizations have been established, suggesting that such bodies offer one of the best means for dealing with international fisheries problems.

Comparison of Present Commissions

All four tuna bodies (IATTC, ICCAT, IOFC, and IPFC) are concerned with conservation of tuna and tuna-like species within their areas of geographical responsibility. The IATTC and ICCAT are independent commissions established by international treaties and are therefore responsible to the contracting parties. The IPFC and IOFC are established within the FAO and are regional bodies subject to control of the FAO Conference and Council; their activities are carried out through their parent body (Carroz and Roche 1967). The ICCAT has an agreement which provides for appointment of an FAO representative who participates, without the right to vote, in meetings of the Commission and its subsidiary bodies.

All four bodies are similar in that their treaties and agreements contain no provision on their legal status, nor do they specify their capacity under international law or national legal systems to perform their duties. This is common to all intergovernmental fisheries bodies except one, the International Council for the Exploration of the Sea, which provides for such legal status and capacity in its convention. Though international fisheries bodies have not been granted legal status they have nevertheless been able to perform legal acts necessary to their objectives on an ad hoc basis, including contracts and transactions relating to the purchase of equipment, hiring of staff, chartering of vessels, and leasing of premises. However, there is no basis for these organizations to enforce their rights, and in certain instances the lack of legal status has obstructed the timely performance of their duties. Even though these ad hoc arrangements have generally sufficed to permit operation of the international bodies in the past, it would appear desirable that conventions creating such bodies include a provision establishing their legal capacity to perform acts necessary to accomplish these duties.

Methods for funding the four bodies differ markedly. IATTC and ICCAT funds are contributed by the member governments in a prescribed manner. Members of IATTC pay in proportion to the amount of fish originating from within the convention waters utilized by each member, regardless of who captured it. Contributions by member states of the ICCAT are determined on the basis of catch and utilization, and by membership on panels. The conventions of IOFC and IPFC do not provide for an operating budget; these commissions rely on the FAO for support.

With regard to commission staff, two kinds of arrangements have been made: IATTC has a full scientific research staff, under the supervision of a Director of Investigations; IPFC has no staff except an elected Chairman and Vice-Chairman, and relies on committees composed of member countries to do technical work. Between these extremes is ICCAT which has a permanent secretariat to attend to administrative matters but relies on panels and committees composed of scientists from national sections for research.

There are pros and cons concerning scientific staff within international fisheries commissions. Most of these revolve about the acquisition of basic data, primarily catch statistics, and the conduct of independent research, free of national policies. A discussion has been presented in Joseph (1972a), who concluded that because of the technological and economic development of the major share of the tuna-fishing nations, the widespread distribution of the resources, fleets and markets, the high-seas nature of the tuna themselves, and the success of fisheries commissions with research staffs, commissions could attain their objectives more efficiently if they maintained independent research staff.

The four bodies differ regarding the geographic areas and species of fish for which they are responsible, as described in detail in foregoing sections. Thus the world oceans have been partitioned into regional areas for the purposes of tuna management. The question is whether this is the best way to approach the problem.

Consider the distribution of the animals which are the objects of management. Research has shown that tunas are in general highly migratory. Albacore and northern bluefin tuna make transoceanic migrations; in 1 year albacore off the east coast of Japan migrate to the west coast of North America. Northern bluefin tagged off the eastern United States of America have been recovered in northern European waters, in the Bay of Biscay, and off Brazil. Catch information suggests that albacore and yellowfin found in the southeast Atlantic Ocean may occur later in the southwest Indian Ocean. Skipjack tuna migrate from the eastern Pacific, where they are only seasonal visitors to the central Pacific Ocean. Recent studies based on genetics of protein systems suggest that a single skipjack subpopulation occurs from the mainland of the Americas to about 150°E, and a second subpopulation from there to mainland China. Southern bluefin tuna are a single, intermingling population distributed circumpolarly throughout the Atlantic, Indian and Pacific Oceans. Yellowfin tuna are more migratory than originally thought. Thus tunas do not recognize imaginary boundaries, and those created by the four commissions are not realistic for management.

Problems of imaginary boundaries can include those introduced by jurisdictional claims of the coastal states, regardless of the breadth of such zones. The animals themselves do not recognize these boundaries and tuna conservation programs based on them will not work. No unilateral or multilateral action taken within territorial seas, whatever the breadth, will lead to proper management. Therefore, in formulating fisheries conventions, the convention area with respect to scientific research and management should include all areas within the range of the fish under study including, if appropriate, the territorial waters of the coastal states. An example is the IATTC, whose convention waters are the eastern Pacific. It has already been demonstrated that for skipjack tuna certainly, and for yellowfin tuna possibly, the westward extent of the convention waters does not include the entire range or population of animals. The southern bluefin tuna will present even greater problems if it becomes necessary to manage this species, because they comprise a single subpopulation and occur within the convention waters of all four bodies. The geographic areas of responsibility

need to be based more on biological parameters and less on political ones.

Not only are the fish themselves highly migratory but the fleets that capture them operate over vast areas. In a single year one vessel may fish in the Atlantic, Pacific, and Indian oceans. When management decisions are made, this great fleet mobility must be taken into account.

With regard to management, only the IATTC has implemented a regulatory program. (The ICCAT has recommended a minimum size limit for yellowfin tuna but this will not become effective until 1973.) The first step in implementing regulations is a recommendation for management based on scientific evidence from the Commission's staff. The Commission recommends action to the Contracting Parties. The Commission also actively seeks cooperation in the conservation program of nonmember governments who fish for tuna in the eastern Pacific. Each participating nation implements the regulations which apply to their vessels. Responsibility for enforcing these regulations lies within each country. Tuna fleets are developing in many nations who had none or small ones at most. As these fleets grow it becomes of tremendous importance that legislation and mechanisms for enforcement be established by the countries. This is even more significant if we note that the Tuna Conventions Act of the United States of America states that regulations for the control of tuna fishing in the convention waters shall not be promulgated ". . . prior to an agreed date for the application by all countries whose vessels engage in fishing for species covered by the conventions in the regulatory area on a meaningful scale, in terms of effect upon the success of the conservation programme, of effective measures for the implementation of the Commission's recommendations applicable to all vessels and persons subject to their respective jurisdiction. The Secretary of the Interior shall suspend at any time the application of any such regulation when . . . he determines that foreign fishing operations in the regulatory area are such as to constitute a serious threat to the achievements of the objectives of the Commission's recommendations."

The United States is the major producer of tuna in the Convention area, and without the participation of the United States there could be no effective program.

The establishment of national agencies to enforce laws on a high-seas fishery such as tuna is complex and expensive — so much so as to impede the entrance of some developing nations into the tuna fisheries. Serious consideration should therefore be given to international enforcement or inspection systems for tuna fisheries. However, it is most important when considering establishment of such systems that they be kept separate from the scientific arms of commissions, for when scientific and enforcement functions are combined, both suffer.

Future Arrangements

In the earlier sections of this paper it was shown that the combined catches of the principal market species of tuna have remained relatively constant recently though fishing effort has increased substantially. For some of these species catches have declined sharply over earlier levels. Similarly, combined catches of billfishes have not increased in recent years though fishing effort for them has increased, and for some billfish species catches have declined. With four research and management bodies for tuna in existence, why is total catch stabilized and the catch for some species declining? Something in the present institutional arrangements is inadequate. The most obvious shortcoming is a lack of adequate data on catch and fishing effort.

Statistics of total catch by species, and estimates of the amount of fishing effort, in terms of days fishing, days absence, tons of capacity at sea per month, etc., from a significant sample of the fleet are fundamental to the study of fishery dynamics. Of nearly equal importance are samples of length measurements, which represent the size distribution of the exploited population. The IATTC handled this problem with its own scientific staff, whose first task was collection of these data. The other three bodies were not provided with research staffs. ICCAT has a permanent secretariat which has made a heroic effort to compile statistics, but a lack of funds makes the task nearly impossible. The IOFC and IPFC have no staff for collection and compilation of such data, and assessment of their tuna stocks has been impeded.

On numerous occasions scientists have stressed the need for adequate statistics for the tuna fisheries, and have predicted the difficulties that would be faced without them. At the FAO-sponsored World Scientific Meeting on the Biology of Tunas and Related Species, held in La Jolla, California, in 1962, a special working group was established to consider the problem of catch and effort statistics. The group pointed to the shortcomings of the then current collections and suggested mechanisms for improvement (FAO 1963). The Expert Panel for the Facilitation of Tuna Research, established by FAO, has similarly on numerous occasions pointed to the strong need for better statistical data (FAO 1964, 1966). Likewise, a group of experts discussing the dynamics of world tuna stocks pointed to the urgent need for much improved statistics of catch and effort (FAO 1968). All of these recommendations were made a number of years before the tremendous expansion of the world tuna fleet took place, but little was done. Only now are political sectors recognizing the urgent need for statistical data. A recent joint meeting of a Special Committee on Management of Indi-Pacific Tuna recommended that a staff of several professionals, plus supporting staff, be established to obtain the necessary statistical information for adequate scientific assessment of tuna stocks in the Indo-Pacific region. At the Second Regular Meeting of the Council of ICCAT, a resolution was adopted which pointed to the deficiencies in Atlantic tuna catch-effort statistics and the need for adequate funding of the Secretariat to collect better data. The resolution recommended as an interim measure that member governments assist in the data collection by offering to provide technical experts to the ICCAT Secretariat.

The awareness that catch statistical data are essential to the study of tunas is gratifying to scientists, but this is only part of the problem. Of equal importance is analysis, because it provides the assessments of stocks necessary to recommend management measures.

How can present arrangements be modified to obtain the objectives of rational harvest? One way might be to provide ICCAT, IOFC, and IPFC with their own staffs,

with sufficient funds and personnel to collect and analyze statistical data on their fisheries. Before discussing this let us examine several points emphasized earlier.

The total catch of tuna is taken by approximately 40 countries. Of these, two countries, Japan and the United States of America, take about 60% and utilize about 75%; six take nearly 85% and 36 countries catch the remaining 15%. Tuna are wide-ranging, highly migratory fish. They make transoceanic migrations and do not recognize boundaries. Fleets that capture tuna are highly mobile; individual vessels can and do fish tuna in all oceans during a single year.

Considering these factors, it would be redundant and economically inefficient for four bodies to work on nearly identical problems in isolation. At a minimum these should be a single entity responsible for collection of statistical information. This could be accomplished by the creation of a new body or by expansion of responsibility in an existing one. Likewise, because the collection of data and its subsequent analysis are so closely interwoven, it would appear most practical that the same body do both. This was pointed out by the FAO group of stock assessment experts cited above:

"There is an urgent need for an improvement in the statistics of total landings, species composition, and fishing effort. Because of the nature of the fisheries, long-range vessels and vessels landing in foreign countries, the collection, tabulation and publication of detailed statistics might be better done for the world as a whole, rather than for each ocean separately."

They go on to state:

"The Pacific tuna fishery is based on the same species, is largely carried out by the same countries (and indeed, often the same vessels), and supplies the same market as the Atlantic and Indian Ocean Fisheries. It is therefore unrealistic to consider any one of these oceans in isolation as regards statistics, scientific research or management."

Others have pointed to the need for a more integrated approach to the problem of research and statistics. Rothschild (1970, 1973) has extended the need for such an integrated approach to all aspects of fisheries research and management, including sociopolitical and economic ones. He has suggested that we have not adequately recognized the need to develop techniques to handle these complex problems of fisheries management. He has discussed systematic techniques for studying such problems on a broad and comprehensive basis. Such an approach appears necessary to develop research and management programs for tuna that recognize the complexity of the fishery.

All these facts suggest the need for a single body with responsibility for collection of statistical data on tuna fisheries of the world, assessment of the condition of the stocks supporting these fisheries, and subsequent recommendations for management.

This concept is by no means new and has been discussed in detail by, among others, Kask (1969), Joseph (1972a), and Gulland (1972), and it formed one of the major agenda items at the recent meeting of the FAO's Committee on Fisheries.

Such an arrangement could be structured in a number of ways, but one which appears practical is to establish a scientific group whose responsibilities would apply to the tuna fisheries of the world, and would include inter alia: 1) collection and compilation of basic catch-statistical data, size-composition data and other biological information; 2) scientific analysis of such data to assess the effect of man's activities on the abundance of the stocks of tuna under study; 3) timely advice to the High Contracting Parties on the condition of the stocks of tuna; 4) if and when management programs are implemented, the current (on a nearly daily basis) collection and estimation of total catch by gear, area, and flag, to establish closure dates, areas, and other forms of regulations.

Such a scientific group would have to be funded and administered by some political entity. The scientific arm of the body would need to be endowed with its own research staff and a sufficient budget to carry out its duties. Its responsibilities should include all species of tuna and tuna-like fishes listed in the FAO Yearbook of Fishery Statistics which spend all or part of their life on the high seas. Its geographic area of responsibility should be worldwide. Its primary concern should be with the principal market species and billfishes; however, it could provide excellent background data and guidelines for development of fisheries on the secondary species.

The political body could be structured in a number of ways. It could be a number of regional groups, or a single body. The latter would appear to be most efficient but may be more difficult to establish and administer. Its responsibilities would be to make recommendations for management to the High Contracting Parties on the basis of advice from the scientific arm. Its responsibility could include all the tuna and tuna-like species wherever they occurred. Its membership would be open to all nations who are engaged in tuna fisheries, and not restricted to the United Nations or FAO family of nations. The major tuna-fishing nations, those capturing and utilizing in excess of, say, 75% of the total catch of tunas, would need to be members. The objectives of the political body should not be too restrictive with respect to conservation. For example, it should not be limited to the attainment of maximum physical yield, but should be free to examine alternate forms of management which might be optimized through consideration of economic, social, and other factors. This could include an arm composed of economists and political scientists to advise the political body on such matters. The political body should also be authorized to recommend an international inspection system or enforcement arm to facilitate implementation of its recommendations for conservation.

Whether a format for future study and conservation of tuna such as the one outlined above or some other arrangement is instituted, it is clear that some alteration of existing arrangements is required. It must be responsive to the dynamic nature of the fish themselves and of their fisheries; it must be responsive to the needs of the developing tuna fishing nations and of those already highly developed, and it must consider problems of tuna research and management over a broad time horizon.

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