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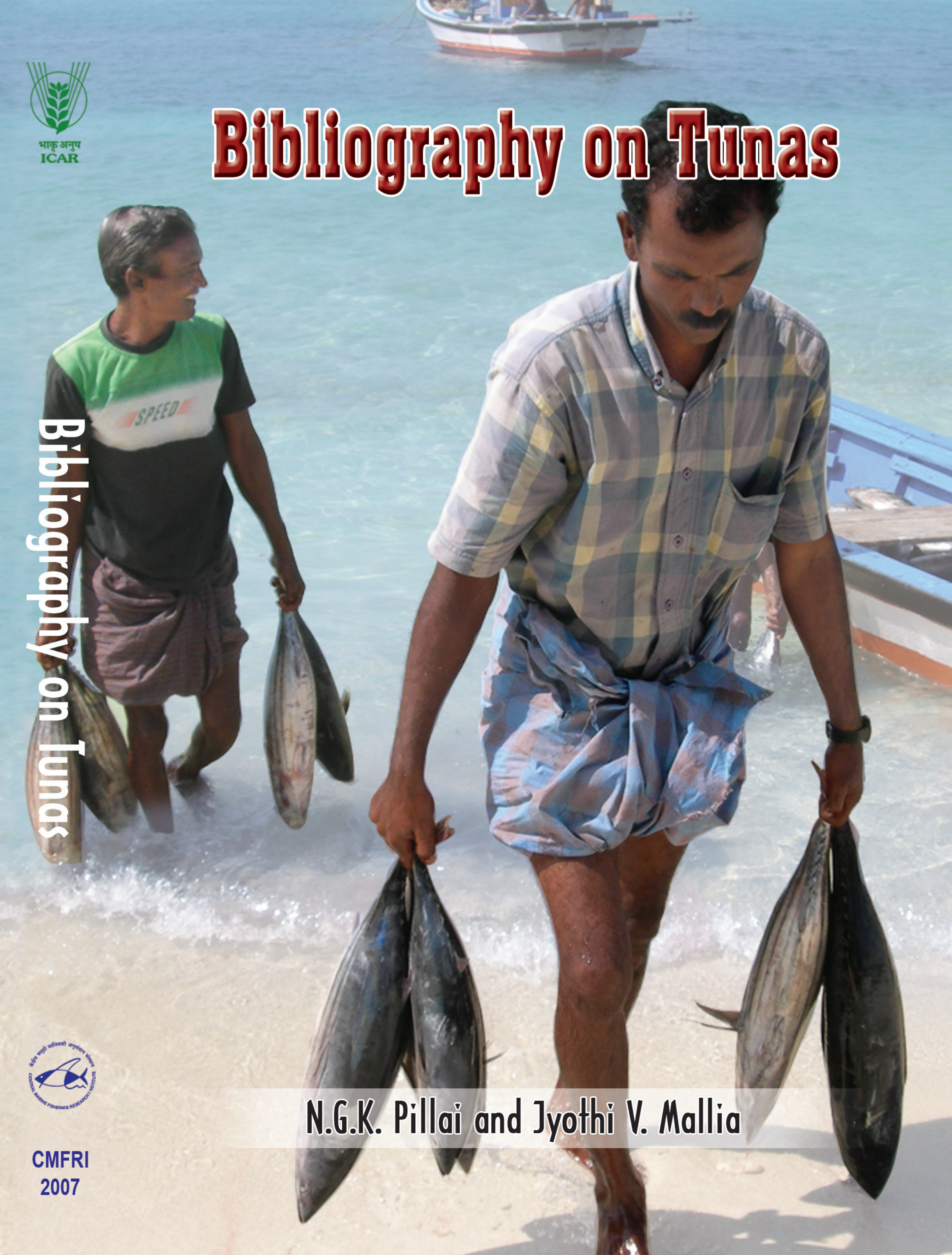
Bibliography on Tunas



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N.G.K. Pillai and Jyothi V. Mallia

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CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P.B.No. 1603, Kochi - 682 018, India

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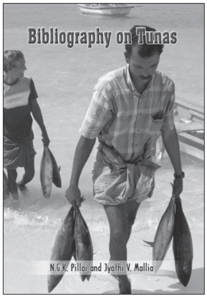

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N. G. K. Pillai and Jyothi V. Mallia

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Phone (off) : 2394867 / ...Ext. 2391407
Telegram : CADALMIN EKM
Telex : 0885-6435 MFRI IN
Fax : 0484-394909
E-mail : mdcmfri@md2.vsnl.net.in

केन्द्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
पोस्ट बॉक्स सं 1603, एरणाकुलम, कोचीन-682 018

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
P.B.No. 1603, Cochin – 682 018, India

FOREWORD

Tunas are highly valued food fishes targeted by coastal fishers as well as distant water fishing nations. Different species of tunas occur in the neritic and oceanic waters and are caught by using diverse types of fishing crafts and gears. World tuna landings touched the record high of 4.3 million t in 2005. Tuna is the second largest product in the international seafood trade constituting over 15%. Tuna fishing and fisheries have become priority theme while addressing issues of development, utilization and management of fisheries in India in the light of EEZ regulations and other international conventions. One of the highlights of the recently held 20th Annual Governing Body meeting of the InfoFish was that of tuna fishing. Tunas are expected to receive cardinal importance in the Indian marine fishing industry in the coming years.

Research and development efforts on tuna and tuna fisheries in the country and abroad have contributed to a rapid growth of literature. A great volume of literature documented over the years, remain scattered in various national and international journals, proceedings, bulletins, special publications and post-graduate and doctoral theses. It is extremely difficult for a researcher to access information from these publications, especially from the grey literature.

Central Marine Fisheries Research Institute has been giving due attention in documenting bibliographies on various topics. The Institute has published over a dozen such bibliographies on various aspects of finfishes and shellfishes. In the present endeavour entitled ***Bibliography on tunas*** includes list of references on fishery, biology, stock assessment, tagging and migratory studies, harvest and post harvest technologies, trade,conservation and management. Efforts have been made to include all relevant literature in this bibliography. However, there could be omissions and therefore the present bibliography is not claimed to be complete.

I hope this bibliography will serve as a ready source of reference for future researchers in the field. I appreciate the interest taken and efforts made by Dr. N. G. K. Pillai, Principal Scientist and Head, Pelagic Fisheries Division and Dr. Jyothi V. Mallia, Research Fellow for preparing this bibliography.

This bibliography is an output of the Ministry of Earth Sciences, New Delhi funded project on *Tuna resources of Indian EEZ - An assessment of growth and migratory pattern.* The financial support provided by the Ministry of Earth Sciences is gratefully acknowledged.

Kochi - 18
January 2007

MOHAN JOSEPH MODAYIL
DIRECTOR

PREFACE

Tunas, a very large and charismatic food fish with a wide distributional range, are valuable both in domestic and foreign markets and hence, play a vital role in the economies of many countries especially oceanic Islands. The oceanic waters adjoining the Asia-Pacific region contribute the bulk of the global tuna production. Although they constitute less than 5% of the world commercial catch by weight, they contribute much by dollar value (US $ 5.3 billion). Research and development efforts on tuna resources all over the world have contributed to a rapid growth of literature. The present bibliography is prepared to incorporate all the available publications including electronic references on this commercially important group, so that a large spectrum of researchers in this area would be benefited.

A total of over 2000 titles have been listed in the bibliography under 8 separate sections. In order to facilitate better utilization, a subject index and author index has been included.

The introductory chapter gives a brief description on field identification of tunas. Next two chapters describes about trend in world and Indian tuna fishery, status of major species, tuna farming/fattening, tuna breeding and its prospects, fishing practices, processing, trade and management of this highly migratory/straddling group.

We express our deep sense of gratitude to Prof. (Dr.) Mohan Joseph Modayil, Director, Central Marine Fisheries Research Institute (CMFRI), Cochin for guidance and encouragements. We wish to place on record our indebtedness to the Ministry of Earth Sciences, Govt. of India, New Delhi for the financial assistance. The authors are grateful to Prof.V. Ravindranath, Advisor and Dr. V.N. Sanjeevan, Scientist-E, Centre for Marine Living Resources and Ecology, Cochin for all encouragements and support. We gratefully acknowledge the liberal help extended by Smt. U. Ganga, Scientist, Smt. Bindu Sanjeev, Stenographer, Shri. B. Jabbar, Shri A.I. Muhsin, Research Fellows and Shri. Edwin Joseph, Librarian, CMFRI, Cochin.

We hope this book on ***Bibliography on tunas*** will be a useful information base for the future researchers and students in the field by enabling them to have a rapid survey of relevant literature.

N.G.K. PILLAI
Principal Scientist and Head,
Division of Pelagic Fisheries

JYOTHI V. MALLIA
Research Fellow

Kochi - 18
January 2007

ACRONYMS

ATL	Atlantic Ocean
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CIFNET	Central Institute of Fisheries Nautical & Engineering Training
CMFRI	Central Marine Fisheries Research Institute
EEZ	Exclusive Economic Zone
EU	European Union
FADs	Fish Aggregating Devices
FAO	Food and Agricultural Organization
FFA	Forum Fisheries Agency
FOC	Flag of Convenience
FRP	Fiberglass Reinforced Plastic
FSI	Fishery Survey of India
GFCM	General Fisheries Commission for the Mediterranean
GPS	Global Positioning System
h.p.	Horsepower
IB	Inboard
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IFP	Integrated Fisheries Project
IOTC	Indian Ocean Tuna Commission
IUU	Illegal, Unreported and Unregulated
LDCL	Lakshadweep Development Corporation Limited
MPEDA	Marine Products Export Development Authority
NIOT	National Institute of Ocean Technology
OAL	Overall length

OB	Outboard
PFRP	Pelagic Fisheries Research Programme
SPC	Secretariat of the Pacific Community / South Pacific Commission
WWF	World Wildlife Fund

Species codes

KAW	Kawakawa *(Euthynnus affinis)*
FRI	Frigate tuna *(Auxis thazard)*
BLT	Bullet tuna *(Auxis rochei)*
BIP	Indo - Pacific bonito *(Sarda orientalis)*
LOT	Longtail tuna *(Thunnus tonggol)*
DOT	Dog tooth tuna *(Gymnosarda unicolor)*
ALB	Albacore *(Thunnus alalunga)*
BET	Bigeye tuna *(Thunnus obesus)*
BFT	Atlantic bluefin tuna *(Thunnus thynnus)*
PBF	Pacific bluefin tuna *(Thunnus orientalis)*
SBT	Southern bluefin tuna *(Thunnus maccoyii)*
SKJ	Skipjack tuna *(Katsuwonus pelamis)*
YFT	Yellowfin tuna *(Thunnus albacares)*

Gear codes

BB	Baitboat
GILL	Gillnet
LL	Longline
OTH	Other gears
PS	Purse seine
SURF	Surface gears
TRAP	Trap
TROL	Troll

1. Field identification of tunas from Indian seas

Scombroids are a diverse group of pelagic fishes ranging in size from about 30 cm to over 3 m in length. Most of them, especially the tunas and billfishes perform considerable and sometimes even transoceanic migrations. Being highly valued table fishes, they are of significant importance both as a commercial and recreational fishery. In Indian waters, this group includes,

1. Tuna and tuna-like fishes belonging to 6 genera, namely, *Thunnus*, *Katsuwonus*, *Euthynnus*, *Auxis* (tribe Thunnini) and the bonitos, *Sarda* and *Gymnosarda* (tribe Sardini)

2. Four genera of Billfishes, namely, *Istiophorus*, *Makaira* and *Tetrapturus* (family Istiophoridae) and *Xiphias* (family Xiphiidae)

3. Mackerels of the genus *Rastrelliger* (tribe Scombrini) and Spanish mackerels of the genera *Scomberomorus* and *Acanthocybium* (tribe Scomberomorini)

Species wise field identification characters and line diagrams of tunas are presented below:

Euthynnus affinis (Cantor, 1849. Kawakawa. Little tunny):

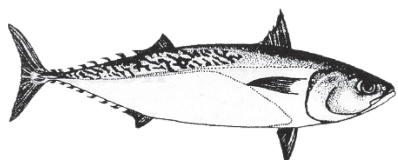
Euthynnus affinis

A medium sized coastal species. Upper part of body has numerous blue black broken wavy lines directed backwards and upwards while belly is silvery white. The first and second dorsal fins are contiguous. A few conspicuous black spots are present on sides of body between pectoral and pelvic fins. Scales on body are confined to corselet and lateral line only. Exploited throughout the year with peak fishing season April to November on west coast and June to August on east coast. Common size in commercial catches is 40 - 60 cm. Local names in the various maritime states of India are:

KERALA (KER): *choora;* KARNATAKA (KAR): *Peepa kedar, Bugudi;* MAHARASTHRA (MAH): *Bugudi, Kuppa, Gedar;* GUJARAT (GUJ) *: Gedara;* ANDHRA PRADESH (AP) *: Palsoora, Mayapusoora;* TAMIL NADU (TN) *: Parunsoorai;* ORISSA (OR): *Tumbada;* WEST BENGAL (WB): *Khabu khabu;* MINICOY (MIN): *Latti*

Auxis thazard (Lacepede, 1800) (Frigate tuna):

A medium sized, robust bodied coastal species of tuna. Dorsal part of the body contains oblique to nearly horizontal dark wavy lines. The first and second dorsal fins are widely separated. Scales on body are confined to corselet, which is short, narrow (4 - 5 rows of scales wide) and abruptly ending. Common size in commercial catches 25 - 40 cm.

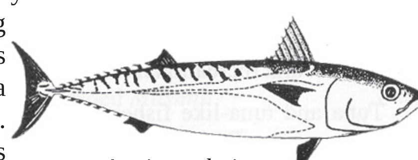


Auxis thazard

KER: *Choora; Elichoora;* KAR: *Kedar,Baremeenu, Bugudi;* MAH: *Bugudi, Kuppa, Gedar;* TN: *Elisurai;* GUJ: Gedara; AP: *Thikkasoora;* MIN: *Ragondi*

Auxis rochei (Risso,1810) (Bullet tuna) :

A small sized coastal species of tuna. Upper part of body bluish with about 15 fairly broad nearly vertical dark wavy lines. The first and second dorsal fins are widely separated. Long, tapering and wide corselet of scales (contains more than 6 row of scales wide in a line below second dorsal) present. Common size in commercial catches 15 - 25 cm.

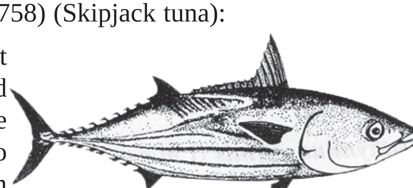


Auxis rochei

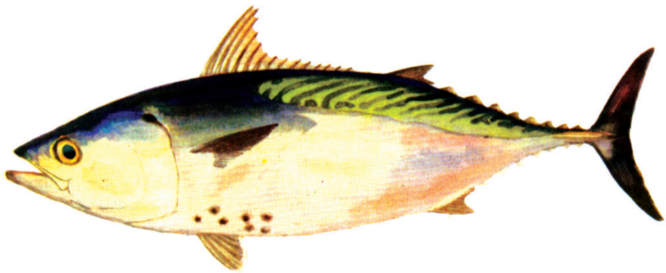
KER: *Urulanchoora, Elichoora;* KAR: *Sheerad, Kedar, Bugudi;* TN: *Elisurai;* MIN: *Ragondi*

Katsuwonus pelamis (Linnaeus, 1758) (Skipjack tuna):

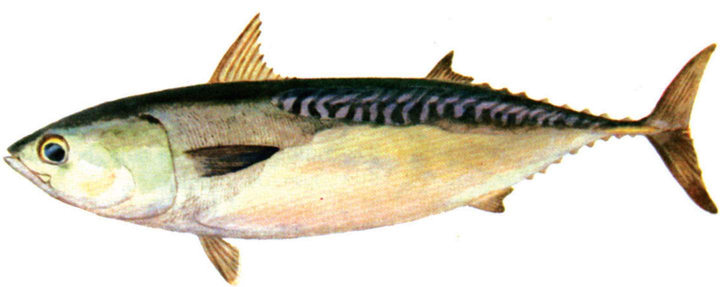
An oceanic species with a robust body. Backside metallic blue tinged with violet and three to five conspicuous longitudinal, dusky to black stripes below lateral line on each side of the body. First two dorsal fins separated by a short



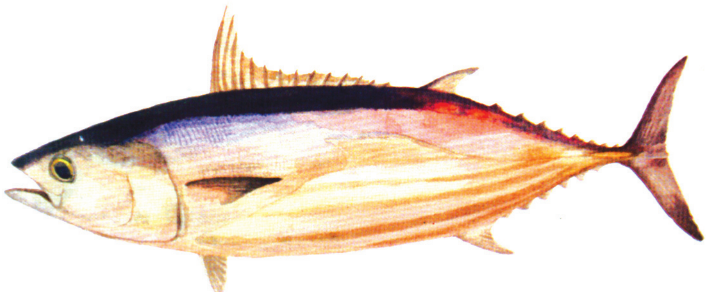
Katsuwonus pelamis



KAWAKAWA
Euthynnus affinis



FRIGATE TUNA
Auxis thazard



SKIPJACK TUNA
Katsuwonus pelamis

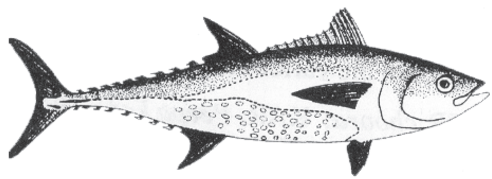
YELLOWFIN TUNA
Thunnus albacares

interspace. Lateral line with downward curve below second dorsal. A major fishery by pole and line in Lakshadweep waters with peak fishing during December - April period. Common size in commercial catches is 40 - 60 cm.

KER: *Varayan choora;* MAH : *Bugudi, Kuppa, Gedar;* AP: *Namalasoora;* TN: *Varisoorai;* GUJ: *Gedara;* OR: *Disco tumbala;* MIN: *Kalibilamas*

Thunnus tonggol (Blecker, 1851) (Longtail tuna):

Body fusiform and rounded, completely covered with very small scales. A comparatively long caudal region. Upper part of body bluish black and lower part of belly with pale streaks or spots, oriented horizontally. Tips of second dorsal and anal fin faintly tinged with yellow. Common size in commercial catches 40 - 70 cm.

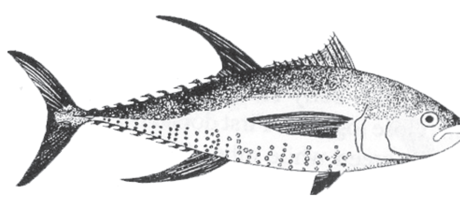


Thunnus tonggol

GUJ: *Sherva;* MAH: *Khavalya;* TN: *Kila valai;* AP: *Soora*

Thunnus albacares (Bonnaterre,1788) (Yellowfin tuna):

Body elongate and fusiform, metallic blue or blue black above and belly with about 20 broken nearly vertical pale lines. Entire body covered with very small scales. Dorsal and anal fins very long in large specimens while pectoral fin is moderately long (reaching beyond second dorsal fin origin). Differentiated from bigeye tuna by distinct notch (V) in caudal fin with larger and more pronounced caudal keels. Common size in commercial catches 50 - 150 cm. Large specimens are caught in longlines operating in oceanic waters and also by the troll line and the pole and line fishery in Lakshadweep seas. Juveniles are caught from coastal waters.



Thunnus albacares

KER: *Manjachoora;* TN: *Kilavalai;* AP: *Reccasoora;* GUJ: *Gedara;* MAH: *Bugudi, Kuppa, Gedar;* MIN: *Kannelimas, Reendhoouraha kanneli;* LAK : *Poovanchoora.*

Thunnus obesus (Lowe, 1839) (Bigeye tuna):

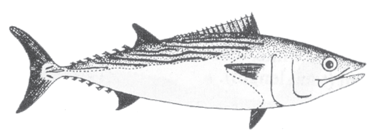
A large oceanic species with a very broad and robust body that is slightly compressed laterally and completely covered with scales. Upper part of body black to greenish blue while sides and belly are silverywhite. Caudal portion is short while eyes and head are fairly large. The first dorsal fin is deep yellow, second dorsal and anal fin slightly yellow while finlets are bright yellowish edged with black. Caudal fin is widely expanded. Caught mainly by longlines with peak catches during October to May. Common size in commercial catches 60 - 180 cm.

Thunnus obesus

LAK: *Valiyachoora;* MIN: *Boduloe kanneli.*

Sarda orientalis (Temminck of Sehlegel, 1844) (Oriental bonito):

A small and slender bodied coastal tuna with 5-11 dark oblique stripes on back and upper sides. Body entirely covered with small scales and a well developed corselet. Lateral line conspicuously wavy. The fishing season on the south-west coast is June to September mainly by drift gill nets. Common size in commercial catches 30 - 50 cm.

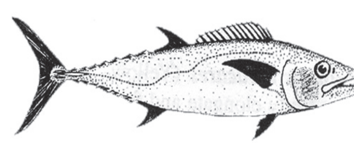


Sarda orientalis

KER: *Choora;* KAR: *Bugudi;* TN: *Seela soorai;* OR: *Tumbada;* WB: *Tumbada.*

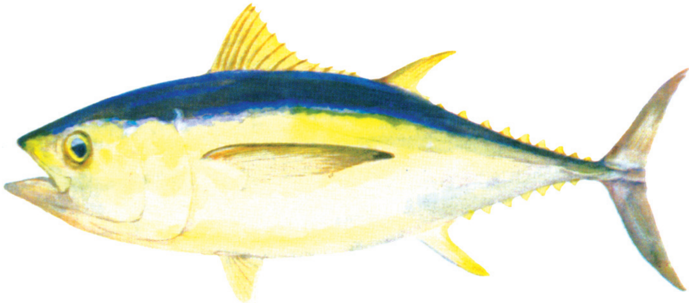
Gymnosarda unicolor (Ruppel,1836) (Dogtooth tuna):

Body slender and elongate, without any spots or stripes. Back and upper sides brilliant blue black with belly silvery. Dorsal fins close together. First dorsal fin bluish green while other finlets is dusky blue. Distal portion of second dorsal and anal fins are whitish. Conspicuously large, well developed and conical teeth present in both jaws. A large single interpelvic process present. Common size in commercial catches 40 - 60 cm.

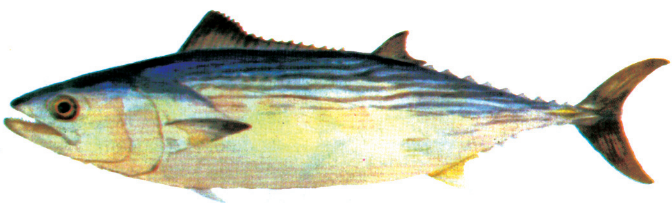


Gymnosarda unicolor

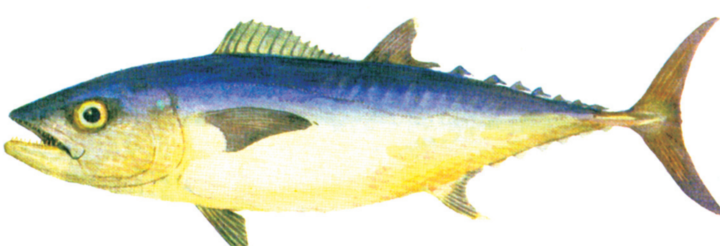
KER: *Choora;* KAR: *Bugudi;* MIN: *Vorikanneli;* LAK: *Pallanchoora.*



BIGEYE TUNA
Thunnus obesus



STRIPED BONITO
Sarda orientalis



DOGTOOTH TUNA
Gymnosarda unicolor

2. Trends in world tuna fishery

Tunas have been important to mankind for several thousand years. Archaeological evidence shows that early humans harvested tuna more than 6,000 years ago, and tuna products may have been among the earliest processed fisheries commodities traded among ancient civilizations. Currently, fishermen of nearly 80 nations harvest tuna from the world's oceans. The harvest is consumed in many forms: raw, cooked, smoked, dried and canned. They were commonly known as "Chicken of the sea" and form the second largest product in international seafood trade with about 9% of the total trade in value terms.

Tuna occurs in temperate to tropical waters and broadly classified into coastal/neritic and oceanic species. The principal market species of tuna were skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), albacore (*Thunnus alalunga*), northern bluefin (*Thunnus thynnus*), and southern bluefin (*Thunnus maccoyi*). Temperature (thermocline) and food availability (areas of convergence and divergence) are reported to influence their distribution and abundance. Tunas show distinct migratory routes, spawning and feeding locations.

In the scientific and popular literature, tunas are most often described as highly migratory fishes "wanderes" of the world's ocean. Their highly charged life styles as apex predators in the oceanic pelagic environment are facilitated by a number of anatomical, biological and physiological specializations.

Tuna have demonstrated their speed and stamina in long distance migrations and International organizations and scientists of many nations have gathered data on these migrations through tagging studies. From these studies, we know that albacore tuna migrate from the coast of California to the coast of Japan, a trip of over 8,500 km moving on average of not less than 26 km per day. Northern bluefin tuna have traveled at least 7,700 km across the Atlantic Ocean (ATL) in 119 days, a sustained journey of over 65 km per day. A tagged skipjack tuna released 200 km south west of the tip of Baja California was recaptured west of Enewetak in the Marshall Islands, a distance of nearly 9,500 km. Tagged yellowfin tuna have been recovered within 620 km of the site of their release.

World tuna fishery a time line

Since the nineteenth century, and indeed since ancient times, tuna fishing has been carried out in many places in the world. These fisheries were local and generally near the coasts. As most species of tunas are highly migratory, these fisheries caught tunas only at certain points in their life cycle and thus had to be seasonal. They included, in the Atlantic, purse seining for bluefin off Norway, trolling for albacore in the Bay of Biscay, trap fishing in the Straits of Gibraltar and along the North African coast, Pole and line fishing for bigeye and skipjack near islands and artisanal fishing along the coasts of Africa. In the Pacific, there were various artisanal fisheries near islands in tropical waters, troll fisheries for albacore and baitboat fisheries for yellowfin and skipjack off the west coast of the United States of America, baitboat fisheries for skipjack near Japan, and many other fisheries for various tunas along the coasts of Japan. Coastal fisheries using baitboats and small seine nets existed off South America. In the Indian Ocean, fisheries for skipjack existed off Sri Lanka, India and the Maldives and southern bluefin tuna were the target of longline fishing off Australia.

As a result of increasing demand for tuna for canning, industrial fisheries started during the 1940s and 1950s. In 1960s, Spanish and French baitboats and purse seiners started fishing for tunas off tropical West Africa, and were joined by Japanese baitboats. Also, Japanese longliners expanded their fishing area all over the world, still targeting mostly albacore and yellowfin for canning. In 1965, the Republic of Korea and Taiwan Province of China started large scale longline fisheries, learning the techniques from Japan, for exporting tuna to the canning industry. At the end of the decade, the Japanese longline industry developed extremely cold storage systems, which established new frozen products for the *sashimi* market, and consequently started to change their target species from yellowfin and albacore to bluefin and bigeye tunas. At this time in the Pacific, the US baitboat fishery off Central and South America was almost completely replaced by purse seiners, which developed a new fishing method, called dolphin fishing. Schools of yellowfin tuna associated with dolphins, a phenomenon observed only in the eastern Pacific, were their major target, and speedboats were used to chase the tuna into the net, together with the dolphins.The purse-seine fishery by European nations in the tropical eastern Atlantic developed quickly, targeting yellowfin and skipjack in 1970.

The tremendous increases in production during 1970 - 1978 period were the result of expansion of the fisheries in the eastern Atlantic and the development of new offshore fishing areas in the eastern Pacific. Subsequently, after six years of little increase in world production, many vessels transferred to the western Pacific and western Indian Ocean, where they developed new fishing grounds. The catches during this period showed the greatest rate of growth seen in the fishery in many decades. During 1980, many new countries entered the large scale industrial fisheries, mostly with purse seiners (e.g. Brazil, Mexico and Venezuela). Small scale longline fishing operations also started in coastal countries in various areas (e.g. Mediterranean countries, Indonesia and the Philippines).

Starting in the 1980, and increasingly in the 1990, many coastal states, in all oceans, started new tuna fisheries by chartering flag of convenience (FOC) boats. Some of these vessels changed flag to the coastal state that chartered them, and possibly this tendency will be intensified in the near future.

From 1991 through 1996 catches stayed relatively steady, between about 3.1 and 3.2 million metric tonnes. From 1996 through 1999 the catch increased by about 19%, mostly due to the improvement and increased use of Fish Aggregating Devices (FADs). During this decade, many other coastal countries entered the large scale industrial fisheries, mostly with purse seiners and long liners.

In 1997 the catch reached 3.5 million tonnes, and it has continued to increase to 4.3 million tonnes during 2004 (Fig.1). In this decade, tuna farming (keeping tuna in captivity for a short time for fattening purposes) started as a new industry. This business resulted in increasing price and demand for specific sizes and species of tunas, and hence affected fisheries to a great extent. The relatively small tunas taken by purse seiners that used to be sold only to the canning industry can be now converted to products for the *sashimi* market.

The ocean wise contributions of the tuna during 2004 are shown in

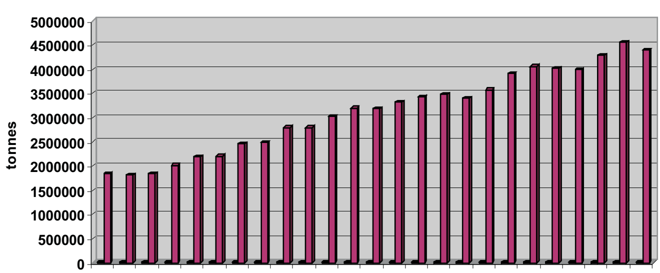


Fig.1 World tuna production1980-2004

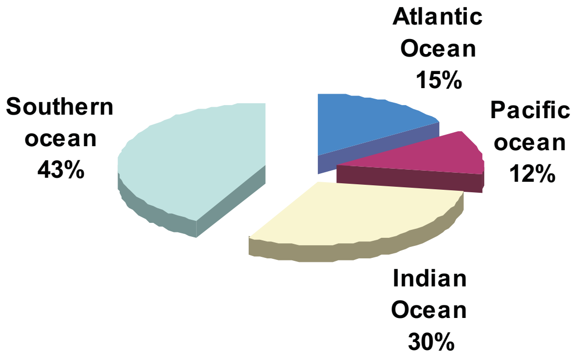


Fig.2 Ocean-wise tuna production during 2004

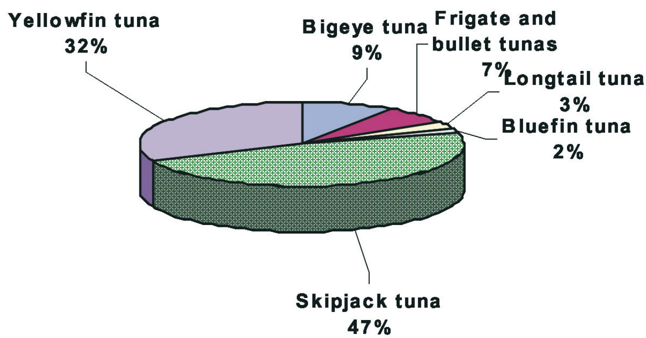


Fig.3 Species composition of world tuna production during 2004

Figure 2 and species wise contribution in Figure 3. In global fish trade, tuna export value grew by 41%, reaching US$ 5.3 billion ($1900million in 1987), while tuna imports grew by 44%, totaling US$ 6.54 billion in 2003. Main tuna catching nations are concentrated in Asia, with Japan and Taiwan (Province of China) as the main producers. Other important tuna catching nations in Asia are Indonesia and Republic of Korea.

Major oceanic tuna species

Skipjack (*Katsuwonus pelamis* (Linnaeus, 1758))

Skipjack is among the most widely distributed of all tuna species, being found in commercial quantities between 45°N and 40°S; inhabits the upper mixed layer of the ocean, and is caught mostly with purse seines and pole and line gear. In terms of weight of fish caught, skipjack is the dominant species in the catch of the Pacific, Atlantic and in the Indian Ocean. During the last several years, skipjack tuna dominated for about 47% of the total world catch of the principal market species. Most of the catch is used for canning. Skipjack is a short lived species, with high rates of natural mortality and population turnover. They spawn year round over vast oceanic areas in equatorial waters, and seasonally where the 24-26°C isotherm extends.

Genetic studies of the Pacific population of skipjack suggest that there is some mixing of fish across the Pacific Ocean, but for management purposes the stocks in the western Pacific are often considered separate from those in the eastern Pacific, as supported by tagging data, which shows limited movement of skipjack between the two areas. Studies based on tagging experiments conducted by the Secretariat of the Pacific Community (formerly South Pacific Commission) (SPC) suggest the stock of skipjack in the western Pacific is under exploited and that it may be possible to increase catches significantly. Such increases would, of course, depend on demand for raw material, price, the ability of the fishermen to locate additional fishing areas, and the vulnerability to capture of the fish in these new areas.

In the Atlantic Ocean, there is no conclusive evidence concerning the stock structure of this species, and skipjack in the eastern and western Atlantic are treated as separate stocks. International Commission for the Conservation of Atlantic Tunas (ICCAT) concluded that the resource was under exploited in both the western and eastern Atlantic.

Skipjack in the Indian Ocean are considered to comprise a single stock, so that any management and conservation measures enacted would have to apply over the entire ocean. Although studies of the stock do not show clear evidence that it is fully exploited, scientists have expressed some concern about the possibility of increased fishing levels adversely affecting stock abundance.

Yellowfin (*Thunnus albacares* (Bonnaterre, 1788))

This species, like skipjack, is widely distributed, but is confined to slightly more tropical latitudes. In terms of weight of catch, the second most important species of tuna is yellowfin, which accounts for more than 30% of the world catch. Yellowfin live longer and reach larger sizes than skipjack. Most of the commercial catch is used for canning, and fish over 10 kg are considered prime raw material for this purpose.

Two stocks of yellowfin tuna are widely distributed throughout the tropical Pacific Ocean, and are caught by longline vessels throughout their area of distribution. They are eastern Pacific and west central Pacific of which west-central Pacific region supports the largest tuna fishery in the world, producing about 35% of the world's yellowfin.

The population of yellowfin in the Atlantic is considered to consist of a single intermingling stock. The fish spawn in equatorial regions of the central Atlantic. Most of the young migrate east to the nursery grounds, where they stay until they are about 65 to 85 cm in length, and then most migrate to the western Atlantic, many returning to the eastern Atlantic fishing grounds at about 110 cm.

It is not known whether yellowfin from the eastern and western Indian Ocean belong to the same stock, but if the two are independent of each other it may be possible to increase yellowfin catches somewhat in the eastern area.

Bigeye (*Thunnus obesus* (Lowe, 1839))

Bigeyes are distributed throughout most of the world's oceans, but they occur mostly in waters below the thermocline. Bigeye make extensive vertical movements and often feed deeper than other tunas. Among their unique adaptations to life at greater depth is a layer of subcutaneous fat, which insulates them from the cold. This fat makes them very valuable in the *sashimi* market, and has made them the target of subsurface longline fisheries. Bigeye mature at the beginning of their third year, at a fork length of about 100 cm. They spawn largely in tropical waters, and growth is relatively rapid. The bigeye tuna is a generally understudied species despite its decreasing value and intensifying importance in tuna fisheries.

In the Atlantic, the Gulf of Guinea is a major nursery area. Young fish often mix in shallow schools with yellowfin and skipjack tunas, often in association drifting objects or seamounts. At larger sizes, big eyes move into more temperate waters.

A recent genetic analysis of Pacific bigeye population by the Pelagic Fisheries Research Programme (PFRP) was unable to detect major subdivisions. Some bigeye move considerable distances, they also demonstrate considerable site fidelity a considerable number of bigeye were captured at the release site after more than 5 years at liberty.

Albacore (*Thunnus alalunga* (Bonnaterre, 1788))

The albacore is widely distributed, mostly subtropical to temperate tuna and are considered to constitute separate north and south stocks in both the Pacific and the Atlantic undertake extensive migrations, seeking optimum conditions for feeding and reproduction. Albacore matures at about 5 years of age and tend to spawn in subtropical waters. Surface fishing with hooks and lines in temperate and subtropical regions accounts for most of the catch of younger fish, while longline fisheries in more tropical waters capture the older fish. Purse-seining accounts for only a very small portion of the total albacore catch. Because of the wide distribution and highly migratory characteristics of this species, levels of catch vary a great deal from year to year. Because of the high demand for its white flesh along with limited supply never exceeding 260,000 tonnes, canned albacore has always fetches a premium price.

Bluefin tuna

Southern bluefin (*Thunnus maccoyii* (Castelnau,1872))

Northern bluefin (*Thunnus thynnus* (Linnaeus,1758))

There are two species of bluefin tuna, southern bluefin (*Thunnus maccoyii)*, found throughout the temperate waters of the southern hemisphere, and northern bluefin (*Thunnus thynnus*), found in the north Pacific and the north Atlantic (Some taxonomists consider that the northern bluefin of the Atlantic and the Pacific are separate species). Southern bluefin spawn in the eastern Indian Ocean, and as they grow they migrate through Australian coastal waters to the high seas, where they are found in the southern parts of all three oceans. In the Pacific Ocean northern bluefin spawn in restricted areas off Formosa and southern Japan, and in the Sea of Japan some of them migrate across the Pacific to off North America, and then return to the spawning grounds in the west as they approach sexual maturity. A few individuals make southerly migrations to areas below the equator in the western Pacific. Bluefin tuna are distributed widely throughout the Atlantic Ocean, northern bluefin occur in most waters north of the equator and in the Caribbean and Mediterranean Seas. Historically they were taken in the western Atlantic as far north as Nova Scotia and as far south as southern Brazil. In the eastern Atlantic they were taken off Norway in the north and as far south as North Africa and throughout the Mediterranean Sea. For management purposes, the population has been divided into an eastern and western stock, with the stock boundary approximately equidistant from the two continents. There is some mixing between the two stocks, however, and some scientists think that the bluefin of the Atlantic Ocean and Mediterranean Sea should be considered as a single stock for management purposes. Spawning occurs in the Mediterranean Sea and the Gulf of Mexico.

They are a slow-growing and long lived species, with some individuals reaching more than 25 years of age. In terms of tonnage landed, bluefin is the least important of the principal market species of tuna; however, these low tonnages believe the commercial importance of the species. Because of their large size, and the colour, texture, and high fat content of their flesh, they are the most sought after species for *sashimi*, and command a higher price than any other species of tuna.

Tuna Farming

Tuna farming also known as tuna penning, tuna aquaculture, tuna ranching, and tuna mariculture is a proactive means to increase the tuna industry efficiency while reducing tuna species exploitation. For this tuna are captured at sea by purse seine netting and transferred to a specialised towing seacage. The cages are then slowly towed, sometimes large distances, to growout sites. Once the fish are transferred into the growout cages, they continue to be fed a diet of fresh baitfish, squid, pellets, or a combination of these feeds. When fish are fat and is favourable in market, harvesting is generally carried out by net crowding some fish and removing by gaff or diver. The fish are then graded on the basis of condition (weight, defects, fat score) and flesh colour at the processing factory before being airfreighted and chilled. (Although many are now frozen at temperatures below 60°C and shipped in containers.

According to a WWF report released on 11th April 2003 there is threat on tuna farming in the Mediterranean as dwindling of wild tuna populations. In view of this threat, the conservation organization is calling for a moratorium on the development of new tuna farms in the Mediterranean, until its environmental impacts, particularly on tuna stocks, are addressed at the international and national levels. WWF calls on General Fisheries Commission for the Mediterranean (GFCM) and the ICCAT as well as the European Union (EU) to set up effective regulations for tuna farming, aimed at rebuilding the over fished tuna stock.

Tuna Breeding

The organisations involved in tuna breeding research are listed below:

* **Japan** - Kinki University

* **Mediterranean** - EU DOTT Project (Domestication of *Thunnus thynnus)*

* **Panama** - Achotines Laboratory (IATTC- JOFCF - Panama Government)

* **Australia** - Stehr Group's Clean Seas Aquaculture (Arno Bay)

The ***Achotines Laboratory*** of the IATTC in Panama is successfully spawning the yellowfin tuna in land-based tanks. IATTC believes that this is the only successful example of yellowfin tuna breeding in the world. According to Dan Margulies, Senior Scientist, tuna has been spawning almost daily since 1996. Juveniles have been cultured for up to 100 days, and are routinely reared up to six weeks after hatching. IATTC's Tuna Billfish programme has two main responsibilities, one is to study the biology of the tunas of the Eastern Pacific Ocean to estimate the effects that fishing and natural factors have on their abundance and the other is to recommend appropriate conservation measures so that stocks of fish can be maintained at levels that will afford maximum sustainable catches.

Kinki University *has* succeeded in rearing bluefin in captivity for 23 years from the juvenile stage longer than any other research centre in the world. Researchers are now grappling with the challenge of self sustainable farming: obtaining viable eggs from farmed adults, and raising the fry to become the next generation in a continuous cyclical process. In another world first, university researchers have already tagged and released some farmed fry. Their success in advancing bluefin tuna farming technology will no doubt bring changes to the whole fishing industry. The results obtained by the practical research at Kinki University fisheries laboratories are without par, and can proudly claim to be meeting the challenge to sustain the future supply of fish.

The tuna fishing practices of the world

Since the advent of the human race, every type of device imaginable has been used to capture tuna, from spears or harpoons, to dynamite. Probably the first commercial harvests of tuna were made using hand hauled nets and fish traps. These first commercial captures of tuna probably took place in the

Mediterranean Sea. The Phoenicians used fish traps more than three millennia ago to capture bluefin tuna, which they traded throughout their empire. Though such traps are still used to harvest tuna in the Mediterranean Sea, and Japan too, nearly all of the present day harvest of tuna is made from fishing vessels with a variety of gear types and sizes.

Gear types

Purse seines : Purse seiners target mostly yellowfin tuna and skipjack, and on a world scale account for roughly 60% of all the tuna landed. In recent years the purse seine catch of bigeye tuna has been increasing rapidly, mostly due to the increased use of FADs. Scientists have urged caution regarding expansion of fishing effort in the surface fisheries of the western Indian Ocean, and have expressed concern over the fact that the increased use of FADs has increased the catch of small yellowfin, which could be reducing the yield per recruit, and hence the total potential yield.

Longlines : The gear is passive and non selective to the extent that it can capture several species of tunas, plus other types of fish, particularly swordfish and marlins. The gear fishes mostly at depths between 100 and 150 meters, where temperatures are cool and the largest tunas such as bigeye and bluefin which fetch very high prices in the *sashimi* markets of Japan. The majority of large longline vessels target bigeye tuna. The smaller vessels use shorter mainlines and fewer hooks than do the larger vessels and operate mostly in near shore waters. The larger vessels are often supplied by tender vessels, and can stay at sea for extended periods. The largest long line fleets are those of Japan, followed by those of Taiwan, Province of China and Republic of Korea. In terms of tonnage of tuna captured, long lining captures about 14% of the world catch of tunas.

Pole and Line: Pole and line fishing is a two mode type of fishing. Live bait must first be caught before the tuna. The live bait was used to attract the tuna to the vessel where they were caught by pole and line gear. If the tuna were feeding well, and the “chummer” could keep the fish along side the vessel, several tonnes could be captured in a short time. Though pole and line fishing was at one time the major type of tuna fishing in terms of catch, because of improvements in purseseine gear and methods it has diminished in importance.

Trolling: Trolling consists of towing from a vessel, generally less than 20 meters in length, several lines with bait or lures attached. Most troll fisheries target albacore tuna (*Thunnus alalunga*), but several other species are also taken. Trolling accounts for only a very small percentage of the world catch of tunas.

Gillnets: Drift gillnets, which are generally used to capture tunas in the open ocean, consist of a series of individual nets connected together, often exceeding 100 km in length. Because of the high incidental capture of other species, the use of drift gillnets longer than 2.5 km was banned on the high seas by the United Nations. Only a small percentage of the world catch of tunas is taken with gillnets.

Fish Aggregating Devices (FADs): Fish Aggregating Devices are structures located at surface or at midwater depths to take advantage of attraction of pelagic fish to floating objects. A FAD comprises a large anchor (up to 1m), a heavy duty mooring chain (usually about 30m in length) and mooring rope, with about 50 purseseine floats strung at the surface. The ropes and chain are joined using various shackles, rope connectors, splices and thimbles. A flag pole is attached to facilitate finding the FAD. FADs may be placed in shallow (50 - 100 m) or deep (500 - 1,500 m) waters. Deep water FADs attract or aggregate Skipjack (*Katsuwonus pelamis*), Yellowfin (*Thunnus albacares*), and Bigeye tunas (*T. obesus*). FADs anchored a few kilometres off the coast, and in depths of over 500 m are generally more successful in attracting schools of tunas than shallow water FADs. FADs aggregate the smaller tunas (Skipjack and immature Yellowfin, for example) at the surface and larger tunas (such as mature Yellowfin and Bigeye) at depths of 300 - 400 m. FADs called *payaos* have been utilized for centuries in the Philippines to attract migrating tuna. During may, 1977 to July 1979, in Hawaiin waters two types ‘buoy type’ and ‘raft type’ devices were used as aggregating devices of which buoy type attracted numerous pelagic fishes including large schools of skipjack and small yellowfin tunas. FADs can reduce fishing effort and conserve fuel. Tropical tunas and other species are frequently found in association with floating objects. More than 50% of the world catch of tropical tunas come from fishing under FADs (Fig.4). Appropriate observations and understanding of the association phenomenon will enable us to derive fishery-independent indices of local abundance and indicators of the pelagic ecosystems.

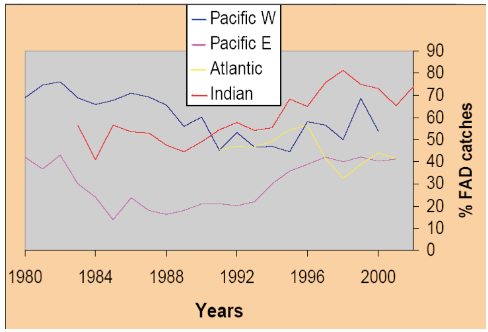


Fig. 4 FAD Percentage of total catch of tropical tunas taken under floating objects

Processing

The main internationally traded tuna forms are raw material for canning (fresh, frozen and frozen pre-cooked loins) tuna for direct consumption (fresh/chilled and frozen) and canned (solid pack, chunks, flakes, grated). Japan is the main world market of tuna for direct consumption (*sashimi*). *Sashimi* originates from fresh raw tuna meat, or from tuna frozen at - 40° immediately after harvest. The *sashimi* market requires the use of larger species, such as bluefin tunas (ensuring the premium *sashimi*) bigeye and yellowfin. Tuna for the *sashimi* market is graded on aesthetic characteristics, such as bright/clear appearance of the skin, clear and moist eyes, elastic skin and undamaged abdominal walls, and on the high fat contents of the fish.

For processing tuna for canning soon after unloading from the vessel they are thawed in running water or sprays of water. They are then quickly gilled, gutted, headed and chilled or frozen. After cutting, the tunas are loaded into trays and taken to the pre-cooker. After precooking and cooling, the cleaners remove the skin from the fish and separate the loins from the skeleton. The last step, canning, is a totally automated process. Canned tuna products are packed in oil, brine, spring water or sauce. After sealing the cans “retort cooking” is done for two to four hours.

It is a relatively common practice in the tuna industry to undertake all the processing stages up to tuna loining as close as possible to the landing areas in developing countries and to export the semi processed product (tuna loins) to canneries in developed countries. Other tuna commodities include dried and smoked tuna, tuna steaks, tuna burgers, tuna jerky, tuna sausage and tuna roe. Animal feed and pet food are produced from processing waste of tuna canneries.

Database for management of tuna fishery

FAO agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks call on nations to work together within regional organizations to maintain lists of vessels operating in their areas of competence which should include all types and sizes of vessels used to catch tunas, rather than just large purse seine and distant water long line vessels. Accordingly several of the regional tuna bodies have taken initiatives to create and maintain databases.

These regional bodies are the International Commission for the Conservation of Atlantic Tunas (ICCAT), Indian Ocean Tuna Commission (IOTC), for the Indian Ocean and the Secretariat of the Pacific Community (formerly South Pacific Commission) SPC, for Pacific ocean, The Inter American Tropical Tuna Commission (IATTC) covering primarily the eastern tropical Pacific and Forum Fisheries Agency (FFA) maintain databases for vessels that are currently and have previously operated in their respective regions. There are, however, areas that fall outside the jurisdiction of these various bodies, for which data is lacking. Most notably these areas represent parts of the west central Pacific. Also the information that is collected by the various organizations is not uniform as some organizations include detailed data and specifications for individual vessels, while others compile only statistics on the numbers of vessels fishing for tunas. Because the problems of tuna management are quite similar throughout all fisheries and areas, and because the vessels move from region to region, there is a strong need to collect detailed information by individual vessel that is comparable among regional organizations. The type of data that should be collected has been clearly identified in the FAO Agreement to Promote Compliance and by some of the regional tuna bodies, and such lists can serve as useful guidelines for collecting and maintaining a vessel database. The kind of information which would be useful to include in any international registry of tuna fishing vessels to be compiled by the regional tuna bodies includes:

* Name of vessel, former names, and registration number
* Flag of registry and previous flag(s) if applicable
* International radio call sign
* Date and location of construction
* Length, beam, and molded depth

* Gross tonnage
* Fish hold capacity in cubic meters
* Fish-carrying capacity in metric tonnes
* Power of main engine (s)
* Fishing method (s)
* Type of aircraft used in fishing, if applicable
* Name and address of registered owner (s)
* Name and address of manager (s)

CONCLUSION

The sea is not so large, nor the human population so small, to exempt even extremely fecund and very widely distributed organisms such as skipjack and yellowfin tuna from concern about sustainability. Bluefin tunas are everywhere depleted. Fishing pressure for Atlantic skipjack and yellowfin has been reported to be at or above maximum sustainable levels. Albacore are over fished and fully exploited in the North and South Atlantic, respectively, while the Atlantic bigeye has rapidly declined. In the Pacific, skipjack are under low to moderate levels of exploitation while yellowfin stocks are under generally moderate exploitation pressure, though increasing effort directed at juvenile yellowfins and big eye appears problematic. As in the Atlantic, Pacific bigeye populations have declined rapidly. Indian Ocean tuna fisheries, management and monitoring are all at an early stage of development, but fishing is increasing.

Future recovery of depleted populations and sustainable management of all these species will require much better commitment and better scientific understanding than have been applied to tuna conservation and management until now. Our action must be swift if we are to ensure that tuna populations are maintained at levels of abundance that can support maximum yields on a sustained basis, to guarantee to future generations to enjoy the benefits of these resources. Implementation of the 1995 UN agreement on high seas and straddling stock fisheries would further help harmonize and improve performance standards for management, conservation and recovery of tuna populations.

3. Status of tuna fishery in India

Tunas constitute one of the important marine fisheries resources of India, having an estimated potential of about 2.78 lakh tonnes in the EEZ. The current average production of tunas from the coastal sector is estimated to be 46,200 tonnes (2005). There are no organized tuna fisheries along our coasts except in the Lakshadweep, where the small scale fisheries for skipjack is established. Long line fishery under chartering foreign vessels to operate in Indian waters commenced in the year 1985 and revised policy on charter was introduced since 1987. The chartered fishing vessels conducted 81 voyages during 1990 and landed about 12,571 tonnes of fishes of which yellowfin tuna constituted 82.3%, bigeye 2.0%. The Government of India survey/training vessels, during their operation from 1983 to 1990 landed a total of 1,244 tonnes of fishes of which yellowfin constituted 743 tonnes. The hooking rate of yellowfin tuna by the exploratory fishing vessels by India (1983 - 90: FSI) has been found to be 1.90 per 100 hooks. Tuna fishing is capital intensive and the fishing industry has not ventured into this field for want of adequate information on the resources, vessels suitable for exploitation, finance, marketing infrastructure and other constraints. However, during the past couple of years harvesting of oceanic tuna has increased due to efforts of the MPEDA.

Trend of fishery

The average annual tuna landings along the mainland during the 1994-2005 period was estimated at 46,204 tonnes (Fig.5) in which the region wise contribution during 2005 was southwest (57%), northwest (20%), southeast (22%) and rest from northeast (Fig.6.). Among tunas *E.affinis* was the most dominant species forming 57% of the catch followed by *Auxis* spp. (16%) *Thunnus tonggol* (9%) *Katsuwonus pelamis* (3%), other species (15%) were *T. albacares, Sarda orientalis* and *Gymnosarda unicolor* (Fig.7). Drift gill nets remain the major gear contributing to the fisheries on the mainland while purse seines, hooks and line, long line, pole and line and troll line are also operated. Pole and line is the most important gear in Lakshadweep islands followed by troll and hand lines.

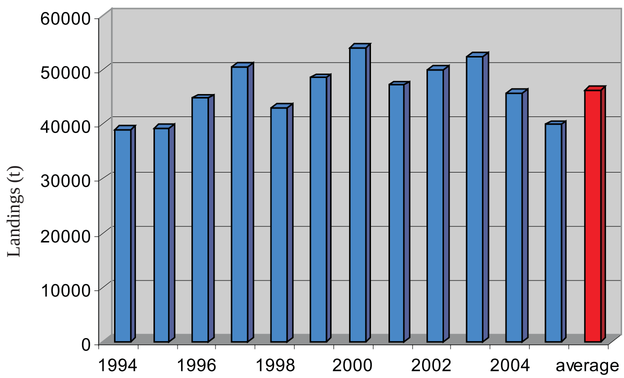


Fig. 5 Tuna landings in India during 1994-2005

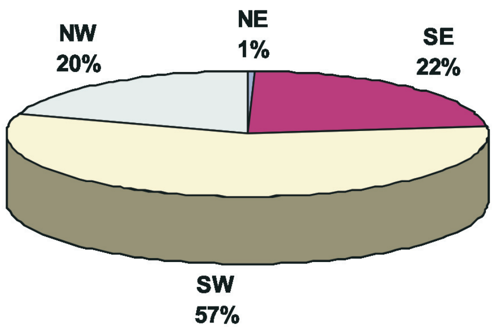


Fig.6 Region- wise tuna production in India during 2005

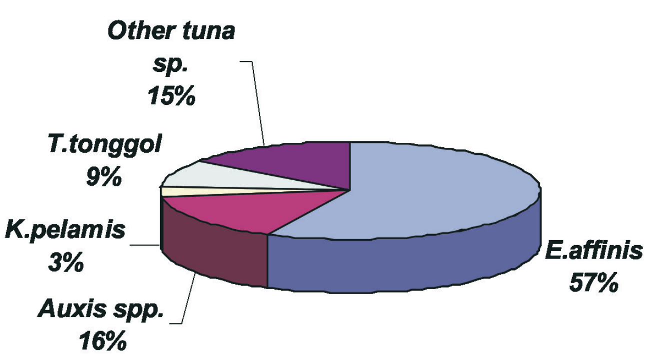


Fig.7 Species composition of tuna landings in India during 2005

During 80s the landings along the mainland were mostly dominated by little tunny (*E. affinis*) and frigate tuna (*A. thazard*), whereas the average landings of longtail tuna (*T. tonggol)* being a mere 663 tonnes and skipjack tuna (*K. pelamis*), about 5,000 tonnes, was landed only from Lakshadweep waters. In comparison, during the 1990 - 2004 period, skipjack tuna is regularly landed on the mainland and the average landings of *T. tonggol* show a manifold increase. Comparison of the species composition of the tuna landings during the 1990 - 94 and 1995 - 2002 period showed that *E. affinis* had declined by 10% but *Auxis* spp. increased while landings of *T. tonggol* doubled. The landings of oceanic species like *K. pelamis* and *T. albacares* has also increased since 1995. Region wise production trends were as follows:

Northwest region

The fishing season is during September to May with peak during October to December. Drift gill nets (mesh 145 - 400 mm *Jada jal*) operate either from wooden or FRP canoes with outboard (OB) engines or plank built boats of 9 - 12 m overall length (OAL) fitted with inboard (IB) engines for tuna fishing. Long tail tuna, *T. tonggol*, a neritic species dominates the landings followed by the coastal tuna *E. affinis* and juveniles of yellowfin tuna *T. albacares* an oceanic species.

Southwest region

In this region, tuna fishing is at its peak during the monsoon period of July to November. The major gears employed are the drift gill nets, hooks and line and purse seine. The total tuna landings, which had peaked during 1990 showed a declining trend until 1995 and thereafter showed a revival. The landings are dominated by *E. affinis*, *Auxis* spp., skipjack and yellowfin. When compared to the early nineties (1990 - 95), during the post 1995 period there has been a decline to the tune of 39% with regard to catches of *E. affinis*, while landings of *T. albacares* and *K. pelamis* has increased. *A. rochei* is another important tuna species in this region whose contribution has increased in the post motorisation period reflecting the change in fishing grounds.

East coast

The peak fishing for tunas along this coast is June - September and January - March off the southeast (Tamilnadu, Pondicherry) and north east (Visakhapatnam) coasts respectively. Gears employed in the fishery include drift gill nets such as *paruvalai* (mesh 80 -160 mm) and *podivalai* (mesh 35-75 mm), long lines, hooks and lines and shore seines of which specieswise abundance is in the order of *E. affinis*, *Auxis* spp. and *K. pelamis*.

Recently, efforts to tap the rich yellowfin tuna fishing grounds in the upper northeast coast off Visakhapatnam has been initiated by traditional fishermen.

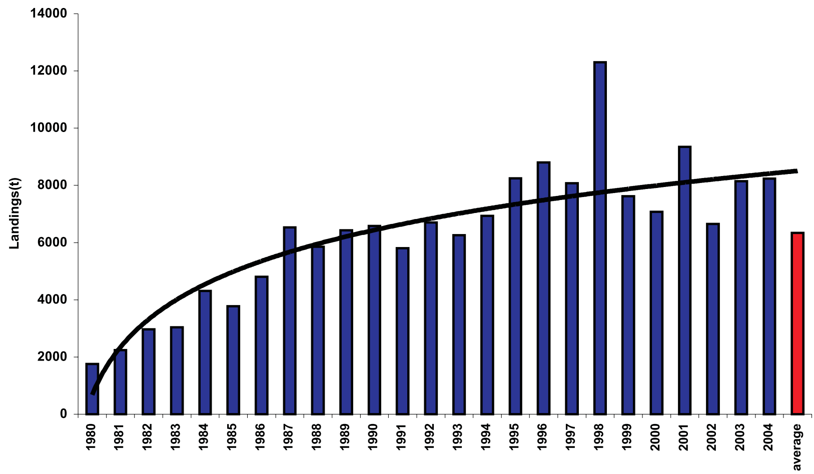


Fig. 8 Tuna landing from Lakshadweep during 1980-2004

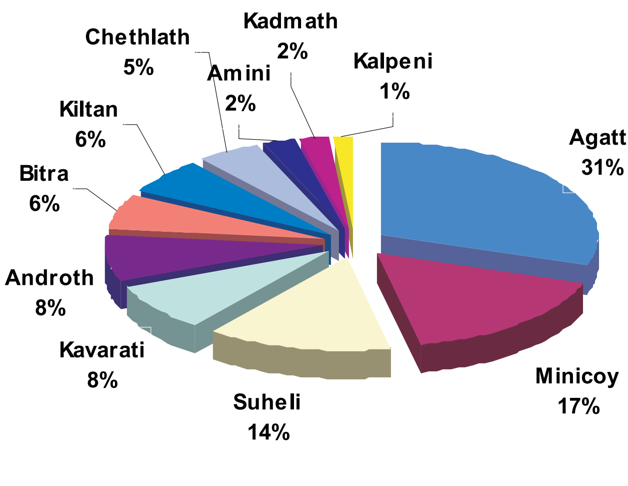


Fig. 9 Island-wise tuna landings in Lakshadweep during 1980-2001 (average)

Lakshadweep seas

During the period 1980 to 2004, annual tuna landings from Lakshadweep has estimated to be between 1,760 tonnes (1980) to a peak of 12,300 tonnes (1998) with an average of 6,339 tonnes (Fig.8). Agatti, Minicoy, Suheli, Androth, Kavaratti, Bitra and Kiltan Islands are the major tuna landing centres of Lakshadweep (Fig.9). The major tuna species landed are skipjack *K. pelamis* (86%) followed by yellowfin *T. albacares* (12%) and little tunny *E. affinis*. Three gears, pole and line (P&L), troll line and hand line have been used for tuna fishing and recently drift gill netting has been adopted in certain islands such as Androth. Difficulty in manoeuvering larger sized boats within the lagoon is perceived as bottleneck in introducing larger boats with higher fish hold capacity. Baitfish (caesionids and sprats) fishing forms an important component of the pole and line tuna fishing of Lakshadweep. Central Marine Fisheries Research Institute introduced Fish Aggregating Devices (FADs) in 2002 in the open sea as well as in the lagoons of Lakshadweep waters to aggregate fishes. Data buoys for Arabian Sea Monsoon Experiments Phase-II deployed by the National Institute of Ocean Technology (NIOT), 16-26 nautical miles off Minicoy and Kavaratti are functioning as FADs aggregating tunas as well as other fishes. It is observed that young tunas aggregate in large numbers than the adults.

In recent years, besides canned tunas and *masmin* frozen tuna export and tuna pickle preparation have also been picking up under the Lakshadweep Development Corporation Limited (LDCL).

Andaman seas

The Andaman and Nicobar islands are some of the best tuna fishing grounds but their contribution to tuna fishery of India is not significant. In 1999, the production of tuna and tuna like fishes contributed 5% of the total marine fish landings of 26,673 tonnes.

Exploratory surveys of tuna resources have been conducted over the years by organizations such as Fishery Survey of India (FSI), Mumbai, Central Institute of Fisheries Nautical & Engineering Training (CIFNET), Cochin and Integrated Fisheries Project (IFP), Cochin. As a development agency, Marine Products Export Development Authority (MPEDA), Cochin is involved in promotional activities for the development of tuna fisheries.

Central Marine Fisheries Research Institute (CMFRI), Cochin as the premier organization in the country for marine fisheries research, has the responsibility for providing guidelines and advice on the rational exploitation, conservation and management of these resources. In fulfilling this objective, the Institute has studied the tuna resources of the Indian Ocean as a whole and has made valuable contributions on the resource characteristics and assessment of the stocks of exploited resources along the mainland coasts and also in and around the Lakshadweep and Andaman-Nicobar Islands.

Prospects

The revalidated potential yield of tunas (2.78 lakh tonnes) from the Indian EEZ were coastal tunas (0.65 lakh tonnes), yellowfin (1.15 lakh tonnes), skipjack (0.85 lakh tonnes) and bigeye (0.13 lakh tonnes), while average annual landings during 1995 - 2004 period indicate that only about 18% of this is exploited. The tuna landing trends during the 1983 - 87 period indicated that along the mainland, the southwest and southeast coasts contributed 68% and 21% respectively of the total tuna landings followed by the northwest coast with 11%. Presently, while southwest coast is still leading in tuna landings, substantial development of tuna fisheries has occurred in the northwest and southeast coasts also. Motorization of country crafts along with multiday fishing has been reported all along the coast which has resulted in increased mobility to offshore tuna fishing grounds and significantly contributed to the increased oceanic tuna landings.

Species composition of the tuna landings through the period from 80s to late 90s are indicating a shifting of fishing grounds to more offshore areas with representation of oceanic species such as skipjack and yellowfin; and neritic species such as frigate tuna *A.rochei* and long tail tuna *T. tonggol* showing an increase. *Pablo* type mechanised boats of 7.6 to 9.4 m OAL were engaged in single day operations at depths upto 50 m during the eighties. But presently with most of these boats having facilities like Global positioning System (GPS), mobile phones and enhanced ice storage capacities, multi day fishing trips of 7 - 20 days at 100 m depths and beyond are common. On the northwest coast multiday fishing operations by drift gillnetters as well as the operation of gill nets during the monsoon from temporarily modified trawlers by removal of deck fittings like winch and gallows has been reported. On the east coast, considerable progress has been achieved in motorization of traditional catamarans with introduction of OB engines and fitting of in-board engines to many artisanal plank built boats and tunas comprising mainly of skipjack and yellowfin are being exploited by traditional sector using troll line, hand line and gill nets. Recently tuna fishing by traditional fishermen targeting yellowfin tuna using hooks and line from catamaran off

Visakhapatnam is picking up. It is also reported that large floating devices have been deployed for tuna fishing in the oceanic waters off Nagapatnam, Tamil Nadu. A pilot project involving conversion of idling shrimp trawler fleet (23 - 27 m OAL) off upper east coast for monofilament tuna longlining is also being implemented by developing agencies and the fishing industry that aims at eventual upgradation of around 30 trawlers for tuna fishing which may create a positive impact on tuna production from Indian waters. According to Marine Product Export Development Authority (MPEDA), Kochi, exports of tuna were 16,627 tonnes in 2005-06 valued at US $ 15.68 million.

The present annual tuna production from Lakshadweep waters which is only about 20% of the estimated potential of the area can be enhanced by adoption of innovative fishing techniques and judicious deployment of fishing units. Usage of FADs, drift gill net fishing and deep long lining, deployment of more units in specific fishing grounds, mother ship and dory fishing operations and erection of artificial reefs close to the islands are suggested for increasing tuna production from Lakshadweep waters.

Availability of required quantities of preferred livebaits (sprats, apogonids, caesionids and pomacentrids) in nearby lagoons to attract tunas and capture them by the chumming process is another serious constraint faced by fishermen of Lakshadweep. Protecting the habitat of baitfish therefore is of prime importance in sustaining the tuna fishery of these islands. In the FAD tuna fishing, the individual sizes of tunas aggregated were found to be smaller than those in natural schools. Assured catches from these grounds are encouraging the fishermen to venture to these fishing grounds with GPS, but further monitoring of the fishery is desirable. It is also necessary to overcome constraints such as availability of adequate quantity of ice and fuel which limits the targets set by the fishermen for catching skipjack tuna and to ensure a good export market for tunas so that the fishing fleet is adequately utilized for exploiting the rich tuna fishing grounds in this sea.

The annual potential yield of tunas in Andaman and Nicobar waters has been estimated at one lakh tonnes. Various species available in these waters are *T. albacares, T. obesus, T. alalunga, K. pelamis, T. tonggol, E. affinis, Sarda orientalis* and *Gymnosarda unicolor.* Peak tuna fishery is reported to be during March to August. The fishing fleet mainly comprises plank built crafts (25 - 35 feet OAL) with in board motors (8 - 15 hp) and dugout canoes of 10 - 22 feet size operating with drift gill nets, shore seines and hooks and line. Among the potential fishery resources, coastal and oceanic tunas and tuna like fishes are the major contributors with yellowfin, skipjack tuna and bigeye tuna dominating the tuna landings. The vessel capabilities, infrastructure and expertise available at Andaman and Nicobar Islands are inadequate to effectively tap the rich tuna and tuna like resources occurring in these waters and hence suitable strategies have to be evolved to expand tuna fishing, preferably involving the idling shrimp trawlers from the mainland coast. The required infrastructure facilities also will have to be developed with support from the local fisheries administration.

It is evident that tuna fisheries have evolved rapidly since the 80s and more of the highly valued oceanic species are represented in the catches. However, most of these developments have occurred as a result of the initiatives taken by fishermen in the small scale sector. They face many constraints right from adoption of a technology (long lining on mainland, gill netting in Lakshadweep waters) to infrastructure availability (adequate fuel and ice) and finally getting a reasonable price for their catch. Although tuna is the second most important item in world seafood trade the contribution by India is negligible. Fishing for tuna is not pursued seriously by the fishermen who perceives the returns as inadequate. Part of this situation emerges due to the fact that the tuna catch is not of *sashimi* grade (which require immediate freezing at $^{-}40^{o}$C) for which the fishing vessels lack onboard/onshore infrastructure facility and also because tuna is less preferred in the domestic market. Hence, it may be considered worthwhile to develop at least a small fleet specifically for tuna fishing with appropriate market linkages so that it becomes an economically viable proposal for fishermen/entrepreneurs who wish to venture for tuna fishing. This in turn will ease the fishing pressure on coastal fishery resources and may be even ease the conflicts between the various fishing sectors in India to a greater extent.

4. Abbreviations of Technical Journals

1.	Acta Oceanographica Taiwanica	*Acta. Oceanogr.Taiwanica.*
2.	American Journal of International Law	*Am. J. of International Law.*
3.	American Journal of Physiology	*Am. J. Physiol.*
4.	American Naturalist	*Am.Nat.*
5.	American Zoologist	*Am. Zool.*
6.	Aquacultural Engineering	*Aquacult. Eng.*
7.	Aquacultural Nutrition	*Aquacult. Nutr.*
8.	Aquacultural Research	*Aquacult. Res.*
9.	Aquatic Living Resources	*Aquat. Liv. Res.*
10.	Archives of Environmental Contamination and Toxicology	*Arch. Environ. Contam. Toxicology.*
11.	Australian Fisheries	*Aust. Fish.*
12.	Australian Journal of Marine and Freshwater Research	*Aust. J. Mar. Freshwat. Res.*
13.	Biological Bulletin of Marine Biology Laboratory	*Biol. Bull. Mar. Biol. Lab.*
14.	Biological Conservation	*Biol. Cons.*
15.	Biological Marine Mediteraneean	*Biol. Mar. Medit.*
16.	Biological Oceanography	*Biol.Oceanogr.*
17.	BMC Evolutionary Biology	*BMC Evol. Biol.*
18.	Boletim de Pesca Lisbon	*Bol.Pesca.Lisbon.*
19.	Bulletin de la Societe de Francaise Japnaise d' Oceanographie., Lamer	*Bull.Soc. Franco Japonaise d' Oceanographie, Lamer.*
20.	Bulletin of Central Marine Fisheries Research Institute	*Bull. Cent. Mar. Fish. Res. Inst.*

21.	Bulletin of Environment of Contamination of Toxicology	*Bull.Environ.Contam.Toxicol.*
22.	Bulletin of European Association of Fish Pathology	*Bull. Eur. Assoc. Fish Pathol.*
23.	Bulletin of Far Seas Fisheries Research Laboratory	*Bull. Far Seas Fish. Res. Lab.*
24.	Bulletin of Fish Research Agency	*Bull.Fish.Res.Agen.*
25.	Bulletin of Fish Survey of India	*Bull. Fish. Surv. India.*
26.	Bulletin of Fish Research Development Agency, Busan	*Bull.Fish.Res.Dev. Agency, Busan*
27.	Bulletin of Freshwater Seas Research Lab	*Bull.Fres.Seas. Res.Lab.*
28.	Bulletin of Inter American Tropical Tuna Commission	*Bull. IATTC.*
29.	Bulletin of Japanese Social Science of Fisheries	*Bull. Jpn. Soc. Sci. Fish.*
30.	Bulletin of Japanese Society of Fisheries Oceanography	*Bull.Jap.Soc. Fish.Oceanogr.*
31.	Bulletin of Korean Fisheries Society	*Bull. Kor. Fish. Soc.*
32.	Bulletin of Marine Science Gulf of Carribean	*Bull. Mar. Sci. Gulf Carib.*
33.	Bulletin of Marine Sciences	*Bull. Mar. Sci.*
34.	Bulletin of Misaki Marine Biology Institute. Kyoto University	*Bull. Misaki Mar. Biol.Inst. Kyoto Univ.*
35.	Bulletin of Natural Institute of Far Seas Fisheries	*Bull. Natl. Inst. Far Seas Fish.*
36.	Bulletin of Natural Research Institute of Aquaculture	*Bull. Natl. Res. Inst. Aquacult.*
37.	Bulletin of Tohoku Regional Fisheries Research Laboratory	*Bull. Tohoku Reg. Fish. Res. Lab.*
38.	Cahiers de Biologie Marine	*Cah. Biol. Mar.*

39.	Cahiers options Meditterranean	*Cah.Options Meditterr.*
40.	California Cooperative Oceanic Fisheries investigations. Reports	*Calif. Coop. Oceanic Fish. Invest. Rep.*
41.	California Department of Fish Game, Fisheries Bulletin US	*Calif. Dep. Fish Game, Fish Bull.US.*
42.	California Division of Fish Game, Fisheries Bulletin	*Calif. Div. Fish Game,Fish Bull.*
43.	California Fish and Game	*Calif. Fish Game.*
44.	Canadian Journal of Fisheries and Aquatic Sciences	*Can. J.Fish. Aquat. Sci., / J. Fish. Res. Bd. Can.*
45.	Canadian Journal of Zoology	*Can. J. Zool.*
46.	Cell and Tissue Research	*Cell Tissue Res.*
47.	Center for International Climate and Environmental Research Oslo Report	*CICERO Rep.*
48.	Central Marine Fisheries Research Institute Special Publication	*CMFRI Special publ.*
49.	Chesapeake Science	*Chesapeake Sci.*
50.	Collective Volume of Scientific paper International Commission for Conservation of Atlantic Tunas	*Coll. Vol. Sci. Pap. ICCAT.*
51.	Commercial Fisheries Review	*Commer. Fish. Rev.*
52.	Commercial Research Statistics	*Comm.Res. Stat.*
53.	Comparative Biochemical Physiology	*Comp. Biochem. Physiol.*
54.	Comparative Parasitology	*Comp. Parasitol.*
55.	Conseil Permanent International Port L' Exploration De La Mer	*Cons.Perm. Int. Explor. Mer.*
56.	Dana Report	*Dana. Rept.*
57.	Deep Sea Research	*Deep Sea Res.*

58.	Department of Agricultural Stock Fisheries Research Bulletin	*Dep. Agric.Stock Fish. Res. Bull.*
59.	Environmental Biology of Fishes	*Env. Biol. Fish.*
60.	Experimental Biology	*Exp. Biol.*
61.	FAO Fisheries Circular	*FAO Fish. Circ.*
62.	FAO Fisheries Report	*FAO Fish. Rep.*
63.	FAO Fisheries Synopsis	*FAO Fish. Synop.*
64.	FAO Fisheries Technical Paper	*FAO Fish. Tech. Pap.*
65.	Far Seas Fisheries Research Laboratory Bulletin	*Far Seas Fish. Res. Lab. Bull.*
66.	Far Seas Fisheries Research Laboratory Division of Oceanography	*Far Seas. Fish. Res.Lab., Div. Oceanogr.*
67.	Far Seas Fisheries Research Laboratory Series	*Far. Seas. Fish. Res. Lab. Ser.*
68.	Far Seas Fisheries Research Laboratory Shimizu	*Far Seas Fish. Res.Lab.Shimizu*
69.	Fish and Fisheries Science	*Fish.Fish.Sci.*
70.	Fish Resources	*Fish. Res.*
71.	Fisheries Bulletin	*Fish. Bull.*
72.	Fisheries Bulletin, US	*Fish. Bull. U.S.*
73.	Fisheries Engineering	*Fish. Eng.*
74.	Fisheries News letter, Australia	*Fish Newsl., Aust.*
75.	Fisheries Oceanography	*Fish. Oceanogr.*
76.	Fisheries Pathology	*Fish. Path.*
77.	Fisheries Research	*Fish. Res.*
78.	Fisheries Research Laboratory, Kagoshima University	*Fish. Res. Lab., Kagoshima. Univ.*
79.	Fisheries Science	*Fish. Sci.*
80.	Fisheries Technology	*Fish. Technol.*
81.	Fishery Survey of India Special Publication	*FSI Spl. Publ.*

82.	Fishing Chimes	*Fish.Chim.*
83.	Fishing News International	*Fishing News Int.*
84.	Food Chemistry	*Food Chem.*
85.	Food Technology Australian	*Food Technol.Aust.*
86.	Global Aquaculture Advocate	*Global Aquac. Adv.*
87.	Gulf Carribean Resources	*Gulf Caribb. Res.*
88.	ICES Journal of Marine Science	*ICES J. Mar. Sci.*
89.	Indian Journal of Fisheries	*Indian J. Fish.*
90.	Indo-Pacific Tuna Programme Collective volume work document	*IPTP Coll. Vol. Work.Doc.*
91.	Informes Tecnicos. Instituto Espanol de Oceanografia	*Inf.Tec.Inst.Esp.Oceanogr.*
92.	Inter American Tropical Tuna Commission, Bulletin	*Inter-Am. Trop. Tuna. Comm. Bull.*
93.	Inter American Tropical Tuna Commission, Special Report	*Inter-Am. Trop. Tuna Comm., Spec. Rep.*
94.	International Commission for Conservation of Atlantic Tunas Collective Volume of Scientific Papers	*Int. Comm.Conserv. Atl.Tunas. Coll.Vol.Sci.Pap.,/ICCAT. Coll.Vol.Sci.Pap.*
95.	International Commission for Conservation of Atlantic Tunas, Standing committee for Research Statistics	*Int. Comm.Conser.Atlantic Tunas.Stand.Comm.Res.Stat.*
96.	International Commission for Northwest Atlantic Fisheries Special Publications	*Int.Comm.Northwest.Atl.Fish. Spec.Publ.,*
97.	International Journal of Marine and Coastal Law	*Int.J.Mar.Coas.Law.*
98.	International Review of Hydrobiology	*Int. Rev. Hydrobiol.*
99.	Irish Naturalists Journal	*Ir. Nat. J.*
100.	Japan Sea Regional Fisheries Research Laboratory Bulletin	*Japan Sea Reg. Fish. Res. Lab. Bull.*

101.	Japanese Agricultural Research	*Jap. Agricult. Res.*
102.	Japanese Association of Advance Science	*Jpn.Ass.Adv.Sci.*
103.	Japanese Journal of Ichthyology	*Jap.J.Ichthyol.*
104.	Japanese Society of Science Fisheries Bulletin	*Jap. Soc. Sci. Fish. Bull.*
105.	Journal Du Conseil, Conseil International Exploration. De La Mer.	*J. Cons. Cons. Int. Explor. Mer.*
106.	Journal of Acoustic Society of America	*J. Acoust. Soc. Am.*
107.	Journal of Agricultural Department, Kinki University	*J. Agric. Dept. Kinki Univ.*
108.	Journal of Agricultural Food Chemistry	*J.Agric.Food.Chem.*
109.	Journal of American Oil Chemical Society	*J.Am.Oil.Chem.Soc.*
110.	Journal of Applied Icthyology	*J.Appl. Ichthyol.*
111.	Journal of Aquatic Food Product Technology	*J. Aquat. Food Prod. Technol.*
112.	Journal of Bombay Natural History Society	*J. Bombay Nat. Hist. Soc.*
113.	Journal of Chemical Ecology	*J.Chem.Ecol.*
114.	Journal of Comparative Physiology. Part A. Sensory, Neural, and Behavioral Physiology	*J. Comp. Physiol.A*
115.	Journal of Comparative Physiology. Part B. Biochemical, Systematic, and Environmental Physiology	*J. Comp. Physiol.B*

116.	Journal of Experimental Biology	*J. Exp. Biol.*
117.	Journal of Experimental Zoology	*J. Exp. Zool.*
118.	Journal of Fish Biology	*J. Fish Biol.*
119.	Journal of Fish Diseases	*J. Fish Dis.*
120.	Journal of Fisheries of China	*J.Fish.China.*
121.	Journal of Fisheries Society, Taiwan	*J. Fish. Soc. Taiwan.*
122.	Journal of Food Technology	*J.Food.Technol.*
123.	Journal of Ichthyology	*J.Ichthyol.*
124.	Journal of Marine Biological Association of the United Kingdom	*J. Mar. Biol. Ass. U.K.*
125.	Journal of Marine Biological Association of India	*J. Mar. Biol. Ass. India.*
126.	Journal of Marine Biology	*J. Mar. Biol.*
127.	Journal of Marine Technology Society	*J. Mar. Tech. Soc.*
128.	Journal of Molecular Evolution	*J. Mol. Evol.*
129.	Journal of Morphology	*J.Morph.*
130.	Journal of Ocean university of China	*J. Ocean Uni. China.*
131.	Journal of Oceanographic Society of Japan	*J. Oceanogr. Soc. Japan,*
132.	Journal of Ocenanographic Department, Takai University	*J. Oceanogr. Dept. Takai Univ.*
133.	Journal of Pacific Marine Science Technology	*J.Pac.Mar.Sci.Tech.*
134.	Journal of Plankton Research	*J.Plankton Res.*
135.	Journal of Seafood Export	*J. Seafood Exp.*
136.	Journal of the Acoustical Society of America	*J. Acoust. Soc. Am.*

137.	Journal of the Shimonoseki College of Fisheries	*J. Shimonoseki Coll. Fish.*
138.	Journal of the Shimonoseki University of Fisheries	*J. Shimonoseki Univ.Fish.*
139.	Journal of Thermal Biology	*J. Thermal Biol.*
140.	Journal of World Trade	*J. World Trade.*
141.	Limnology and Oceanography	*Limnol.Oceanogra.*
142.	Madras Fisheries Bulletin	*Madras Fish. Bull.*
143.	Maldives Marine Research Bulletin	*Mal.Mar.Res.Bull.*
144.	Marine and Freshwater Behaviour and Physiolgy	*Mar. Freshw. Behav. Physiol.*
145.	Marine and Freshwater Research	*Mar Freshwater Res.*
146.	Marine Biological Annual Review	*Mar. Biol. Ann.Rev.*
147.	Marine Biological Association of India. Special Publication	*MBAI Spl Publn.*
148.	Marine Biology	*Mar. Biol.*
149.	Marine Biotechnology	*Mar. Biotech.*
150.	Marine Ecology progress Series	*Mar. Ecol. Prog. Ser.*
151.	Marine Fisheries Haiyang Yuye	*Mar. Fish. Haiyang Yuye.*
152.	Marine Fisheries Information Services T&E Series	*Mar. Fish.Info. Serv., T& E Ser.*
153.	Marine Fisheries Research	*Mar. Fish. Res.*
154.	Marine Fisheries Review	*Mar. Fish. Rev.*
155.	Marine Mammal Science	*Mar. Mamm. Sci.*
156.	Marine Policy	*Mar. Pol.*
157.	Marine Pollution Bulletin	*Mar. Poll.Bull.*

158.	Marine Research Bulletin	*Mar. Res. Bull.*
159.	Marine Resource Economics,	*Mar.Res.Econom.*
160.	Marine Science Bulletin	*Mar. Sci. Bull.*
161.	Marine Technology Society Journal	*Mar. Tech. Soc. J.*
162.	Mathematical Biosciences	*Math. Biosci.*
163.	Memoirs of the Faculty of Agriculture of Kinki University	*Mem. Fac. Agric. Kinki Univ.*
164.	Memorie di Biologia Marina e di Oceanografia	*Mem. Biol. Mar. Ocean.*
165.	Misaki Marine Biology Institute Special Report	*Misaki Mar. Biol. Inst. Spl. Rep.*
166.	Molecular Ecology	*Mol. Ecol.*
167.	Molecular Marine Biology and Biotechnology	*Mol.Mar. Biol. Biotechnol.*
168.	Molecular Phylogentic Evolution	*Mol. Phylogenet. Evol.*
169.	Museum of National historical Occassional paper	*Mus. Nat. Hist.Occas. Pap.*
170.	Nankai Regional Fisheries Research Laboratory Report	*Nankai Reg. Fish. Res. Lab.Rep.*
171.	Natural Fisherman	*Nat.Fisherman.*
172.	Natural Geography	*Nat. Geogr.*
173.	Natural Research Institute of Far Seas Fisheries Bulletin	*Nat. Res. Inst. Far Seas Fish.Bull.*
174.	Natural Resource Modeling	*Nat.Res.Mod.*
175.	New Zealand Journal of Marine and Freshwater Resources	*New Zealand J. Mar.Freshwat. Res.*
176.	NOAA Technical Reports, NMFS	*NOAA Tech. Rep. NMFS.*
177.	North American Journal of Fisheries Management	*N. Am. J. Fish. Manage.*

178.	Oceanography and Marine Biology.Annual Review	*Oceanogr. Mar. Biol. Ann.Rev.*
179.	Oceanologia Acta	*Oceanol.Acta.*
180.	Pacific Fisherman	*Pac. Fisherman.*
181.	Pacific Science	*Pac. Sci.*
182.	Pacific Science Congress Proceedings	*Pac. Sci. Congr., Proc.*
183.	Paper Proceedings for Royal Society of Tasmania	*Pap. Proc.R. Soc. Tasmania.*
184.	Philippines Journal of Fisheries	*Philipp. J. Fish.*
185.	Physiological Zoology	*Physiol. Zool.*
186.	Problems of Ichthyology	*Probl. Ichthyol.*
187.	Proceedings of Geological Survey of India, Special Publication	*Proc.Geol. Surv. India, Spl. Publn.*
188.	Proceedings of Gulf and Caribbean Fisheries Institute	*Proc. Gulf Caribb. Fish. Inst.*
189.	Proceedings of Indo Pacific Fisheries Commission	*Proc. IPFC.*
190.	Proceedings of International Commission for Conservation of Atlatntic Tunas conference on International Skipjack year Prgramme	*Proc. ICCAT Conf. Intern. Skipjack Year Prog.*
191.	Proceedings of International Indian Ocean Expedition Symposium of Biology	*Proc. IIOE Symp.Biol.*
192.	Proceedings of Natural Academy of Science, USA	*Proc. Natl. Acad. Sci. U.S.A.*
193.	Proceedings of Pacific Science Congress	*Proc. Pac. Sci. Congr.*
194.	Proceedings of Symposia on Scombroid Fishes	*Proc. Symp. Scombroid Fishes*
195.	Proceedings of Tuna Meet	*Proc. Tuna Meet.*

196.	Proceedings of US Natural Museum	*Proc.US. Nat. Mus.*
197.	Quarterly Review of Rural Economy	*Q.Rev.Rural.Econ.*
198.	Rapports Process –Varbaux Reunions Conseil International l'Exploration de la mer	*Rapp. P.V. Reun.CIES.*
199.	Recent Advances in Fish Biology	*Rec. Adv. Fish. Biol.*
200.	Record of Canterburry Museum	*Rec. Canterburry Mus.*
201.	Report of Nankai Fisheries Research Laboratory	*Rept. Nankai. Fish. Res. Lab.*
202.	Report of Nankai Regional Fisheries Research Laboratory	*Rept. Nankai Reg. Fish. Res. Lab.*
203.	Report. CSIRO Marine Laboratories	*Rep. CSIRO. Mar. Lab.*
204.	Reviews of Aquatic Sciences	*Reviews Aquat. Sci.*
205.	Revista de Investigacao Pesqueira (Maputo)	*Rev.Invest.Pesq.Maputo.*
206.	Rybnoe Khozyajstvo (Moscow)	*Rybn.Khoz.*
207.	Science et Peche	*Sci. Peche.*
208.	Scientia Marina	*Sci. Mar.*
209.	Scientific Americanna	*Sci. Am.*
210.	Seafood Export Journal	*Seafood Exp. Jour.*
211.	South African Journal of Zoology	*S.Afr. J.Zool.*
212.	South Pacific Commission	*South Pacific Comm.*
213.	South Pacific Commission Fisheries News Letter	*SPC Fish. Newsl.*
214.	South Pacific Commission Occasional Paper	*South Pac. Comm. Occas. Pap.*
215.	South Pacific Commission Oceanic Fisheries Program Technical Report	*SPC Oceanic Fisheries Program, Tech. Rep.*

216.	Specific Scientific Report US Fish Wild Services	*Spec. Sci. Rep. US. Fish. Wild. Serv.*
217.	Standford Icthyological Bulletin	*Stanford Ichthyol. Bull.*
218.	Standing Committee of Research Statistics	*Stand. Comm.Res. Stat.*
219.	Symposium of Zoological Society of London	*Symp. Zool. Soc. London.*
220.	Technical Report Seychelles Fish Authority	*Tech.Rep.Seychelles.Fish.Auth.*
221.	Transactions of Oceanology and Limnology	*Trans. Oceanol. Limnol.*
222.	Transactions of the American Fisheries Society	*Trans. Am. Fish. Soc.*
223.	Transactions of the Chinese Ichthyological Society	*Trans. Chinese Ichthi., Soc.*
224.	Transactions of the Royal Society of South Australia	*Tran. of the Royal Soc. of South Australia.*
225.	U.S. National Marine Fisheries Service Fishery Bulletin	*U.S.Nat.Mar.Fish., Serv.Fish.Bull.*
226.	Underwater Naturalist	*Underwater Nat.*
227.	US Fish Wild Service Circular	*U. S. Fish Wild. Serv. Circ.*
228.	US Fish Wild Service Fisheries Bulletin	*U. S. Fish Wild. Serv. Fish. Bull.*
229.	US Fish Wild Service Special Science Report Fisheries	*U. S. Fish Wild Serv., Spec. Sci. Rep. Fish.*
230.	Victorian Naturalist	*Victorian Nat.*
231.	Virginia Marine Research Bulletin	*Virginia Mar. Res. Bull.*
232.	Voprosy Ikhtiologii	*Vopr.Ikhtiol.*
233.	World Aquaculture	*World Aquacult.*
234.	Zoological Journal of the Linnean Society	*Zool. J. Linnean Soc.*

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Ministry of Earth Sciences
New Delhi, India

Indian Council of Agricultural Research
New Delhi, India

Central Marine Fisheries Research Institute
Kochi, India