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Taxonomic status of marine pelagic fishes of India, research priorities and conservation strategies for the sustainability of their fisheries

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ABSTRACT

The paper briefly reviews the taxonomic status of the marine pelagic fishes of India, lists the research priorities and conservation strategies concerning these fishes. While the taxonomic status of commercially important species/groups of pelagic marine fishes is fairly well determined, the need for such studies on all other lesser known species is pointed out. In the present context of high fishing intensity, minimizing the effects of fishing based on certain biological attributes, would ensure the sustainability of marine pelagic fisheries and the conservation of species.

Key words: Conservation, Fishes, India, Marine, Pelagic, Taxonomy

Marine fish production in the country increased from 0.52 mt in 1950 to 2.71 mt in 2006. Pelagic fin-fishes contributed 55% of the total all India marine fish production. West coast of India contributes to the bulk of pelagic fish catches. There are about 250 species of pelagic fishes belonging to 12 families but only 60 species belonging to seven groups, including the oil sardine, lesser sardines, anchovies, Bombay-duck, ribbonfishes, carangids and the Indian mackerel form the major fisheries (Pillai & Katiha, 2004).

Certain unique biological characteristics and environmental parameters together cause wide oscillations in the catches from year to year. The single species fisheries of the oil sardine, Indian mackerel and the Bombay-duck easily tilt marine fish production of the country in any year. Therefore, sustained production of marine pelagic fishes is crucial for maintaining and enhancing total marine fish production of the country.

Hitherto, the country's efforts to increase marine fish production have been focused only on commercially important species. Therefore, taxonomic, biological and fishery oriented studies have been mostly limited to, but intensified on such species. Sixty years of continued and mostly uncontrolled exploitation of marine fisheries resources in the coastal region, facilitated by the open access system coupled with modernization of crafts and gears, led to overcapitalization and over-fishing of some resources. Though some offshore and oceanic resources remain to be tapped fully, the situation, as far as the coastal resources are concerned, warrants taking remedial measures, for the seeds of destruction of resources and degradation of the environment are evident for quite some time.

In this context, the present paper reviews the taxonomic status of marine pelagic fishes, research priorities and conservation strategies for the sustainability of their fisheries.

BIOLOGICAL AND FISHERIES CHARACTERISTICS OF MARINE PELAGIC FISHES

Biological Characteristics: Through belonging to distinct families, the marine pelagic fishes have certain unique biological characteristics. Many of the species form massive schools and migrate long distances along the coasts and from inshore-offshore and *vice-versa*. They grow very fast but have short life span. Breeding process is quite prolonged, often throughout the year, shedding the gametes in batches at short intervals. They are highly fecund; eggs and larvae are small, transparent and pelagic. They feed on plankton.

Fisheries Characteristics: The pelagic fisheries are characterized by the dominance of the oil sardine (*Sardinella longiceps*), the Indian mackerel (*Rastrelliger kanagurta*) and the Bombay-duck (*Harpadon nehereus*). These species together account for more than a quarter of total marine fish landings in any year and hence adverse effects of any fishery dependent or independent (environmental) factor on any of the species would tilt the total marine fish production to the negative side and conversely, a favourable factor, to the positive side. Such a vulnerable situation often causes socio-economic upsets along the west coast, where these fishes are prevalent and predominant. While these are highly fluctuating fisheries, there are others, despite continuous and

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Table 1. The average landings of pelagic fin-fishes and their percentage contribution during 1990-2005

Group	Catch (tonnes)	(%)
Oil sardine	224,655	18.2
Mackerel	163,832	13.1
Carangids	142,385	11.4
Ribbonfishes	129,540	10.4
Anchovies	116,098	9.3
Bombay-duck	110,696	8.6
Lesser sardines	97,306	7.8
Other clupeids	47,720	3.8
Tunas and bill fishes	45,950	3.7
Seer fishes	43,950	3.5
Hilsa shad	25,359	2.0
Wolf herrings	15,251	1.2
Barracudas	14,040	1.1
Other pelagics	70,372	5.6
Total pelagics	1,246,901	

Source: Pillai & Katiha, 2004

intense fishing over the years, exhibit increased production. They are exemplified by the lesser sardines, *Hilsa* spp., Whitebaits, *Thryssa* spp., *Coilia dussumieri*, carangids and ribbonfishes. The only fishery which had declined significantly was that of the unicorn cod (*Bregmaceros mclellandi*). Another characteristic is the area-specific nature of the dominant species. The oil sardine, Bombay-duck and unicorn cod are mostly restricted to the west coast, the grenadier anchovy (*Coilia dussumieri*) to the northwest and northeast coasts. Research indicated that the distribution and abundance of certain species is restricted to certain geographic regions mostly dependent on environmental conditions and food availability, which also fluctuate and vary from year to year. Table 1 shows the average landings of pelagic fin-fishes and their percentage contribution during the period 1990-2005.

TAXONOMIC STATUS

Taxonomic research on fishes in general and other taxa of the animal kingdom was conducted extensively in the earlier periods by the Zoological Survey of India and the Indian Museum at Calcutta. Limited taxonomic research was also carried out on fishes by several universities and Institute. The Central Marine Fisheries Research Institute (CMFRI), which is primarily concerned with research and development of marine organisms, from the production point of view, made several taxonomic contributions on marine invertebrates, fishes, reptiles and mammals, mostly in the 60s and 70s. Quite a few of these works are of classical nature and the only ones of their kind to-date. By and large, all the major and minor marine pelagic species have been studied and the results have been published. These studies have been mostly based on classical and traditional methods of taxonomy including morphometric measurements, meristic counts, body shape, colour *etc*. However, difficulties have been experienced in identification of species due to overlap in morphometric measurements and meristic counts. Colour patterns, though quite diagnostic in several species, soon disappear on death and altogether vanish on preservation. In many species, especially the coral reef fishes, colour patterns remain important tools for identification. In traditional taxonomic methods, to further supplement and confirm the identity, certain anatomical features, like dentition, gill rakers, pyloric caecae and osteological characters have been taken into consideration. The electrophoretic studies have also been made use of for confirmative evidence.

Table 2 indicates the major taxonomic categories of marine pelagic fishes and their species diversity. In the past, in-depth taxonomic research was conducted mostly by the CMFRI on the sardines, whitebaits, wolf herrings, other clupeids, coastal and oceanic tunas, seerfishes, mackerel, ribbonfishes, carangids, Bombay-duck, halfbeaks and mullets.

Very extensive and exhaustive research on the taxonomy of these pelagic fishes have been accomplished based on field

Table 2. Major taxonomic categories of pelagics and their species diversity

Family	Group/Species	Species number
Clupeidae	Oil sardine*	1
	Lesser sardines*	
	(including rainbow sardines)	14
	Hilsa spp. and other shads	15
	Whitebaits*	24
	Thryssa and Thrissocles spp.	10
	Wolf herrings	2
	Other clupeids	40
Scombridae	Coastal tunas	5
	Oceanic tunas	2
	Seerfishes and wahoo	5
	Mackerels*	3
Trichiuridae	Ribbonfishes*	8
Carangidae*	Round scads	2
	Golden scads	6
	Hard tail scad (horse mackerel)	1
	Jacks	17
	Black pomfret	1
	Others	19
Harpodontidae	Bombay-duck*	1
Stromateidae	Pomfrets	2
Coryphaenidae	Dolphinfishes	2
Rachycentridae	Cobia	1
Mugilidae	Mullets	22
Sphyraenidae	Barracudas	7
Exocoetidae	Flying fishes	10
Bregmacerotidae	Unicorn cod	1
	Others	19
	Total Pelagics	240

*Major pelagics
Source: Pillai & Katiha, 2004

collections, representative of their geographical distribution, in the seas around India. They have covered examination of holotypes, paratypes and syntypes of species. Synonymies of individual species, status of nominal species, nomenclatorial changes, earlier revisions and reviews, scanning of world literature on the concerned species have been taken into consideration for confirmation of species identity. Such studies indicated the possibility of wrong identifications due to close external resemblance, concurrent occurrence of similar looking species in the same area and inadequate sampling. Due to various reasons, some well defined species could exhibit wide variations in shape, colour, distribution and even reproductive behaviour, when they are considered from different populations, stocks or races of the same species. Some attempts have been made to decipher such populations of oil sardine, mackerel, Bombay-duck and the skipjack tuna. Results indicated the clusters overlapping and confluence of populations and the need for proper delineation of population genetic parameters. This has great implications for fishing since, if the population is homogeneous, fishing at any one place can affect the stock at every other place. If the population is heterogeneous, fishing at one place would not affect the stocks at other places.

To date, the FAO field identification sheets for the fishes of the western Indian Ocean remains the most recent effort on the taxonomic status of Indian marine pelagic fishes and others as well. There is need to conduct such exercises periodically, exclusively for the Arabian Sea, Bay of Bengal and the southern Indian Ocean. Systematic studies are needed on several other marine pelagic fishes like the barracudas, flying fishes, belonids, billfishes and others, especially with reference to biodiversity documentation and ecosystem-based fishing. However, biodiversity should not be synonymised with taxonomy since the latter is the foundation for all biodiversity programmes. It may suffice for biodiversity purpose to identify a species but taxonomic study goes deeper to examine all nominal species of a genus to fix their status based on several considerations (Lundgren *et al*. 2006). There could be several new species or wrong identifications for well known species. Often, a number of larval or juvenile characters may be retained or they would disappear as the fish grows. All such phenomena need critical study for proper identification. Lumping of species and splitting of species also occurs sometimes.

Taxonomic research in general in the country appears neglected. It is clearly a retrograde step. Serious efforts are needed to bring back the subject to its rightful place to progress systematically with all other areas of study for which taxonomy is the key. Universities and several institutions in the country should establish departments/divisions for taxonomy and promote study and research by providing necessary incentives and employment opportunities. In addition to traditional methods of taxonomy, more modern approaches like molecular taxonomy and genome mapping have to be encouraged for faster identification and extensive coverage of geographical areas for animal identification.

RESEARCH PRIORITIES

Obtaining continuing yields from a living resource is a traditional goal in fisheries management. Populations or stocks fall below levels that provide adequate yields or which fail to meet other specified reference points due to several reasons. Key biological characteristics of fishes, environmental factors, habitat alterations, pollution and fishing seriously impact fish production. Fish stock fluctuations and declines have to be continuously monitored and managed for they cause economic and social hardships. Marine pelagic fishes and their life-histories and environmental conditions under which they live and propagate need further research to manage their fisheries. Voluminous data and information have already been generated by the CMFRI in the past, but focused attention on some critical areas mentioned hereafter may be required in future.

Age and Growth: Pelagic fishes have short life span, grow very fast and breed continuously almost throughout the year, shedding the ova in batches. This makes it difficult to accurately determine their age and growth because of overlap in recruitment and successive resultant broods. At present, age and growth of almost all pelagic fishes are determined by indirect methods. Attempts and research are needed for development of direct methods of tagging, and determining daily or monthly growth rates by examination of hard parts like otoliths under electron microscope (Quasim, 1973; Uchiyama & Struhsaker, 1981; Waldron & Ferneke, 1997; Campana & Thorrold. 2001; Santiago & Arizzabalaga, 2005). Depending on the accuracy of methods used, determination of actual age of the fish may vary. This will have serious implications for determining populations, if any, in pelagic fishes like the oil sardine, mackerel and others.

Fecundity: Earlier determinations of fecundity of several species of pelagic fishes could be suspect because of prolonged, intermittent and batch spawning in most of the species. Proper identification of maturity stages in the progressive scale as well as the digressive scale is essential in such cases for determining the correct fecundity. The number of ova in each batch spawned and the number of batches have to be calculated for arriving at the total fecundity. Fecundity calculations have implications for estimating stock sizes *via* the sex-ratios.

Egg and larval surveys at sea: This area remains poorly investigated. Location, identification and quantification of eggs and larvae and calculations of natural mortality rates can directly help to predict the short-term fisheries of many commercially important fishes of the country. Indirectly, such studies will enable assessment of total stocks to confirm statistical estimations.

Recruitment: A very crucial aspect is to understand the

strength of age-classes and hence the total stocks. The success and failure of recruitment beyond the critical life stages determine the magnitude of the fishery. Abundance of recruits may retard growth and cause reduction in fecundity. There can be low recruitment despite continued presence of spawners. Current stock-recruitment models assume recruitment is zero when stocks are extinct. Therefore, there is need to develop new stock-recruitment models.

High fluctuations in fisheries: Certain fisheries like those of the oil sardine, mackerel and the Bombay-duck highly fluctuate from year to year. Several environmental factors are found to be responsible for the same. Amongst them, the onset and intensity of the monsoon, sunspot activity, sea surface temperature, current pattern change, variations in salinity, dissolved oxygen, sinking of offshore waters, sea level and availability of nutrients in coastal waters are believed to be important (Murty, 1965; Murty and Edelman, 1970; Rao *et al*. 1973; Longhurst. and Wooster, 1990; Murty *et al*. 1990; Pillai, 1991; Madhupratap *et al*. 1994; Jayaprakash, 2002; Vivekanandan *et al*. 2008). As the stock strengths are dependent on success of spawning, recruitment and natural mortality, work at sea to monitor these phenomena assume importance in addition to study of other parameters. A combination of rate of exploitation and changes in environmental factors may also cause collapse of stocks. The impending climatic changes due to global warming may further affect stocks of highly migratory species. They need continuous monitoring.

Schooling behaviour: Not much research has been done on the migration and schooling behaviour of marine pelagic fishes. This is of immense value since schooling fishes contribute to high commercial abundance. Such fishes have to be tagged and their movements tracked using all modern methods including use of acoustic and telemetric tags. The schools should also be scouted using remote sensing methods. The schools are generally considered to be spawning, post-spawning or feeding congregations. The composition of the schools, timings, seasons and reasons and routes have to be fully elucidated. Schooling fishes are highly vulnerable to capture at the time of their migration. Even if population size of such species decreases, they can still be targeted profitably and with continuing efficiency. Fortunately, such species, the schools of which are continuously exploited, e.g., ribbonfishes, sardines, anchovies, mackerel, scads, and tuna, have not declined in their strength. However, with increase in intensity of fishing due to high demand for fish, there could be signs of decline in catches, which have to be continuously monitored. Work of the type done by the erstwhile Pelagic Fisheries Project along the west coast of India on schools of fishes at sea needs to be revived and continued.

Trophic models: Very little research has been conducted at sea on the food chains and food webs to understand their components, factors controlling their fluctuations and the links between them and the fish populations. The plankton feeders like the sardines, mackerel and other fishes depend on availability of suitable planktonic organisms. Any upsets in the food chain from the availability of nutrients in coastal waters to upwelling and movement of water masses and currents can cause wide fluctuations in the catches of these fishes. The abundance of various other species up the chain would in turn govern the abundance of higher categories of fish. Therefore, knowledge of seasonal variations in trophic chains is important to understand the availability of fish. Such research should lead to development of trophic models based on time series data.

Predictive models: Some attempts have hitherto been made to forecast the fisheries of some species of pelagic fishes based on environmental factors and were found successful (e.g., the oil sardine). Attempts have also been made to understand fluctuations through mathematical modeling of fishery dependent and independent factors. The highly variable recruitment patterns, dependence on phyto- and zooplankton and the environmental factors that control productivity, climate and other oceanographic phenomena determining pelagic fish abundance have to be considered together for developing forecasting models. Recent research at CMFRI on forecasting of fisheries using Markov chain model appears advancement in this direction (Ayyappan & Pillai, 2005).

Genetic divergence in species: Research on molecular characterization of important marine pelagic species using DNA sequences should be intensified for species identification as well as to distinguish populations, if any, in well established species.

Fish aggregating devices (*FADs*) *and Artificial reefs* (*ARs*)*:* Recent studies conducted in the country by CMFRI and a few other agencies in different locations indicated they are beneficial to fishermen because of capturing valuable species like the tuna, carangids and others. The structures basically provide shelter and forage. However, the economics of operation, durability, and their impacts on other kinds of fishing activities in the vicinity need detailed studies (Mohan Joseph & Jayaprakash, 2003).

STRATEGIES FOR CONSERVATION

According to the FAO estimates, half of the major fish stocks in the world are fully-exploited (close to the maximum sustainable yield-MSY), another quarter overexploited or depleted and the remaining quarter under- or moderately exploited. In India, recent stock assessment of exploited fisheries indicated a number of fish stocks are exploited close to MSY level, some overexploited and some underexploited (Srinath 2003; Srinath and Balan, 2003; Pillai, 2006). Further research is needed to be more specific in this classification. Reports all over the world indicate that the fallacy, 'always there are more fish in the sea', has ended. Most of the world's exploited species are not being assessed or managed and MSY cannot be estimated with much precision in many fisheries

(Mohan Joseph & Jayaprakash, 2003). For developing meaningful strategies for conservation of pelagic fisheries, there is need to critically examine the biological attributes of the fishes and the socio-economic aspects of fisheries that render them vulnerable.

With the open access system in operation for the past 60 years in India, exploited marine fisheries in the coastal area almost reached a peak of production (Dehadrai & Yadava, 2004). Research indicated further increase in fishing intensity would not increase fish production substantially in the presently exploited region up to about 100m depth, except for some marginal increases in certain pockets and from a few underexploited resources. Since the coastal fisheries sector has been beset with all types of necessary evils of indiscriminate fishing, habitat degradation, pollution, sectoral conflicts, declining catches and deteriorating socio-economic conditions of fishermen and local communities, the situation calls for urgent management measures and conservation strategies to maintain the sustainability of fisheries resources. A few significant strategies are outlined below:

A. Effects of fishing

i. *Control of fishing intensity:* It is not only the fishing methods but the intensity of the fishing which has been causing the decline in catches. The excess fleet sizes have to be reduced and regulated. The resources of each region have to be matched with the sizes of fleets of each method of fishing.

ii. *Halting of destructive gear:* Certain fishing gears like the purse-seines, ring seines, the disco-nets and other similar gears, though very effective and productive, have been found to be destructive at least in the coastal areas. Spawning schools of fish and small sized fish are often caught indiscriminately in such gears, which reflect on future catches. Stricter control on the seasons and areas of operation and the mesh sizes of such nets is essential. Use of dynamites and blast fishing should be totally prohibited.

iii. *Regulation of mesh sizes:* The mesh sizes of various fishing nets have scientifically been fixed not to endanger the resources but hardly enforced. There is no alternative to this, if sustainability is to be ensured. Creation of awareness about the damage to resources amongst fishers is a top priority.

iv. *Monitoring of targeted species:* For reasons of high availability, easy capture, quality and consumer demand, certain species may be intensely and continuously exploited. Both artisanal and industrial fisheries can cause population declines in such fishes. Pelagic schooling fishes are quite vulnerable for capture when spawning and feeding schools are encountered. Adverse environmental conditions combined with mass capture of fishes like the oil sardine, mackerel, Bombay-duck, ribbonfishes, carangids, whitebaits, other clupeids and tuna can also lead to diminishing catches. Added to this, young ones of targeted species could be the components of by-catch in other small meshed fishing gears. Habitat degradation of nursery areas of some species and of other species of limited distribution like the coral reef fishes may enhance the damage to stocks. Hence continuous monitoring and regulation of targeted species stocks is one method of conservation.

v. *Capture of non-targeted species:* In the non-selective fishing gears, several species and their young ones are often captured in considerable quantities. Trawls, encircling nets, hooks and lines and traps contribute to such catches. Such species are simply discarded because they are of low value. There is need to conserve such species, especially their young stages, by regulating fishing effort, places of capture and seasons.

vi. *Control on trawling:* Though the trawl fishing in the country has emerged as the most effective fishing method, the damage it caused to fish resources and the sea bottom habitat, benthic fauna and biodiversity in general cannot be denied. Seasonal and non-uniform bans on trawl fishing in different parts of the country are enforced but the results have not been convincing. Further effective controls are required for conserving the resources as well as for protecting the coastal, highly productive benthic habitat. Trawl fishing holiday for two to three years, designation of no-trawling areas based on scientific study and complete diversification of trawling vessels to other methods of fishing seem to be the only alternatives to retrieve the deteriorating conditions of resources and the habitat.

vii. *Saving juveniles and young fishes from capture:* This is a very sensitive measure of conservation of fisheries resources. It is quite evident that future resources are at a stake because of the capture of young stages of fish which would otherwise attain large sizes, live longer and contribute to increased catches. Several non-selective gears are responsible for such destruction. Market-driven forces, especially for small shrimp, also encourage such capture. The mesh sizes of such nets have to be increased depending on the type of species caught. The only solution is to strictly enforce mesh regulations as per scientific recommendations and also ban operation of some of the gears especially targeting young ones. Fisheries extension has to play a key role to educate fishers on conservation of young fishes. Young ones of several pelagic species are captured in such gears at present.

viii. *Retrieval of discards:* Several species of fishes of low value are discarded at sea or at the fish landing centres. Other edible and non-edible species which are crucial for biodiversity are also discarded or destroyed. This

again is a result of operation of non-selective gears. Several regional estimations of discards have been conducted which indicate loss of huge quantities of fish and other biota. Methods recommended for avoiding such wastages have to be adopted.

B. Biological attributes

i. *Protection to spawners:* Several spawning stocks–of pelagic fishes are often captured in different types of nets, especially when they move in large schools. Some rationality in such capture has to be exercised to ensure future production. It is possible to conserve such resources when the congregations are limited to specific areas and seasons. More research at sea is needed to generate specific data and information and also continuous monitoring of spawning aggregations.

ii. *Damage to critical nursery and spawning habitats:* The estuarine and nearshore habitats like the salt marshes, mangroves, seagrass beds, coral reefs and lagoons constitute important nursery grounds for several species of fishes. The coastal productive grounds afford ample forage to young fishes. Antrhopogenic disturbances to such areas can cause great harm to fish resources. Available protective measures have to be enforced.

iii. *High fecundity of pelagic fishes:* Though this could be a contrivance provided by nature to offset high natural mortalities in the early life histories of several pelagic fishes, research indicated the declines in populations do not bounce back to original state of the populations despite high potential to do so. Therefore, continuous monitoring of spawning stocks, eggs and larvae at sea for delimitation of areas is essential to conserve such vulnerable stocks both from fishing and adverse environmental conditions.

iv. *Critical stages in the life-histories:* Different stages in the life-histories of fishes are vulnerable to natural mortalities as well as fishing mortalities. Though it is difficult to identify such stages, ages, sexes and habitats for various species, at least in conspicuous cases, conservatory measures can be taken by restricting fishing in nursery areas or where spawning adults abound.

v. *Catchability of schools of fishes:* Schools of fishes are highly vulnerable to capture. It is profitable to capture them even when they are at low population level. Further research on schooling fishing is needed to conserve their stocks at sustainable levels.

vi. *Precautionary principle and reference points:* For conserving the fishery resources, adoption of precautionary principle and reference points would be required to consider uncertainties in production, population sizes and mortality rates which are not to be exceeded or desirable to maintain.

C. Ecosystem approach

i. *Ecosystem impacts:* Exploited species of fishes are initimately connected to trophic cycles and behaviour controlled by environmental conditions. Competition for food, predation at various levels and pollution of coastal waters determine the abundance of fish populations. Plankton feeding fishes occupy niches in food webs that are critical for production. Therefore, monitoring trophic cycles at sea would yield valuable information on the fluctuations in abundance of fishes for which suitable models can be developed.

ii. *Marine reserves:* Research indicates marine reserves serve the purpose of protection and conservation of resources, biodiversity and habitat improvement. The effectiveness of the existing marine reserves in the country should be reviewed for their role in conservation of fish resources.

D. Implementation of regulatory measures

National and State legislations are available in the form of Indian Fisheries Act 1897, the Wildlife Protection Act 1972, MFR (regulation) Bill 1978 formulated after the EEZ declaration, MFRA of maritime states enacted in 1980, Maritime Zones of India Act 1981, Environment (Protection) Act 1986 etc., for safeguarding the fisheries resources. Regulatory measures include enforcement of closed seasons, closed fishing areas and periods, ban on certain destructive fishing gears and methods, minimum mesh size regulation and minimum legal size at capture. Better management and conservation of fisheries resources and protection of aquatic habitats would, however, depend on how effectively the above regulations are enforced.

CONCLUSION

For achieving the goals of conservation of fisheries resources in general and secure the future of exploited fisheries, there is need for reducing fishing effort, application of precautionary principle and reference points, ecosystem based fishing, work at sea on spawning aggregations, eggs and larval surveys, onboard vessel work on the detection and quantitative estimation on schools of fish as done in the erstwhile Pelagic Fisheries Project off the west coast of India, identification of critical life stages, establishment of effective marine reserves and implementation of regulatory measures.

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