Biological Conservation **19** (1980–81) 51–80

ENVIRONMENTAL CHANGE AND ITS IMPACT ON THE FRESHWATER FISHES OF IRAN

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ABSTRACT

Factors affecting the distribution and abundance of freshwater fishes in Iran are described. These include climate, devegetation, irrigation, and natural water level fluctuations (termed pre-industrial) and such factors related to industrialisation and population increase as devegetation, water abstraction, fishing, pollution, and faunal introductions. Conservation schemes are outlined and commented on and a list of threatened fishes is given.

INTRODUCTION

The purpose of this paper is to describe those factors, both man-made and natural, which affect the distribution and abundance of Iranian freshwater fishes and to record and suggest measures for the conservation of this fauna.

Fishes, particularly those of no economic value, do not receive the amount of attention from conservationists as do birds and mammals since they are not as readily observed and perhaps have less aesthetic appeal. The amateur ichthyologist is a rarity compared with the amateur ornithologist and mammalogist. A responsibility therefore lies with the professional ichthyologist to write about rare and endangered fishes. This is particularly true in a country like Iran which is rapidly becoming industrialised, with consequent dangers to the fauna, and which in addition lacks an extended tradition of concerned amateur naturalists (Scott *et al.*, 1975) and where there have been few studies on fish ecology. Factors affecting distribution and abundance of fishes can therefore only be outlined in general terms

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Biol. Conserv. 0006-3207/80/0019-0051/$02·25

and it is hoped that more specific studies will be forthcoming from the responsible government agencies charged with environmental protection.

Reasons for conservation of fishes need hardly be argued; fishes are important for scientific, cultural, aesthetic, recreational, economic, and educational purposes.

PRE-INDUSTRIAL FACTORS

This section deals with those factors affecting distribution and abundance of fishes from about 8000 BC until the present day. It is important to emphasize that the contemporary fish fauna has suffered from environmental degradation in prehistoric and historical times and that industrial factors are having an exacerbating effect.

Climate

Pluvial conditions in Iran ceased well before the end of the Pleistocene about 8000 BC (Butzer, 1972). Since that time there have been no major climatic fluctuations comparable with pluvials and interpluvials but even so minor fluctuations were of sufficient magnitude to have had an influence on the fish fauna. Butzer (1961) summarises evidence for a minor subpluvial in southwest Asia after a post-Pleistocene arid period. This subpluvial lasted from c. 5500–2350 BC and was characterised by higher humidity and rainfall with luxuriant flora able to thrive in areas where it is too dry today. Distribution of fishes was probably facilitated by permanent rivers and streams which today are intermittent or dry. Inland lakes would have a greater volume of water and perhaps would be connected to adjacent basins, further facilitating fish dispersals and distribution. A more luxuriant flora would reduce surface runoff so that flow regimes of rivers would be more stable, erosion and its destructive effects on watercourses would be reduced and shaded water would have lower temperatures such that stenothermal fishes would disperse more widely through lower parts of drainage basins which today are too warm. The subpluvial was followed by a period more arid at times than today, although this improved towards the end of the last millennium BC and since then there have been only short-term variations in the climate. The onset of drier conditions might well have limited the distribution of the fish fauna and led to the loss or isolation of certain minor drainages.

Ice-melt from the Fennoscandian ice-cap, as late as 4000 BC, contributed large volumes of water to the Caspian Sea which could not be evaporated. An overflow to the Black Sea was then possible (Raikes, 1967). Berg (1948–49) maintains that the silverside *Atherina mochon pontica* var. *caspia* and the pipefish *Syngnathus nigrolineatus caspius* entered the Caspian from the Black Sea in post-glacial times while most other fishes are relicts of earlier transgressions or are migrants from northern waters.

Devegetation

The influence of the climate is difficult to assess because of the disturbance of the delicate equilibrium between climate, vegetation and soil by man. The influence of man on the environment has been the major destabilising factor.

The hunter or food collector burnt sections of the forest to clear the environment. Fire was also used to drive animals. The grazier burnt to stimulate new growth and reduce scrub and shifting cultivation used the slash and burn technique. Even the scorched earth policy of war contributed to degradation of the environment. Domestication of sheep occurred in Iraq and Iran about 9000 BC and goats about 6700 BC and these animals prevent recovery of land devegetated by man through overgrazing. The pig and cattle, domesticated later, also contributed to devegetation by man through overgrazing, and to deforestation on the basis of feeding and pasturage requirements. The Przewalski horse was domesticated in Iran around 4000 BC and the modern horse was introduced in the second millennium BC, both these animals greatly facilitating land clearance (Whyte, 1961). Dorst (1970) moreover states that forest was often identified with savagery, so that clearance had a psychological as well as economic basis. Introduction of iron and the plough in the first millennium BC also resulted in a more effective and greater rate of clearance.

Wood was cut for domestic fuel, for charcoal, for pottery, brick and metal production and for building houses and ships. In time not only trees but also shrubs and finally perennial and annual vegetation was consumed. The extent of deforestation in Iran since the end of the Neolithic (c. 5000 BC) has been summarised by Whyte (1961). The following proportions have been destroyed: three-quarters of the Caspian coast humid forest, one-half of the Caspian mountain humid forest (much of the remainder severely degraded), up to five-sixths of the Zagros oak and oak-juniper forests, and nineteen-twentieths of the Elburz and Khorasan juniper forest. Heavy depletion of the open *Pistacia-Amygdalus* stands, which once covered almost the entire central plateau outside the true desert, is also recorded. Nomads or semi-nomads have been responsible for destruction of plant cover because of extensive grazing, dry farming and charcoal burning, but it has been urban populations which have had the most deleterious effect on the environment.

Devegetation severely affects the hydrological regime with consequent destruction of fish habitats. It reduces rainfall and hence stream flow, and desert encroachment results. Reduction in plant cover affects retention of rainfall; only about 20 % of total rainfall can usually be measured as runoff but in deforested and devegetated areas of the Zagros 70–80 % can be assumed (Whyte, 1961). Torrential flow and flash floods result with deleterious effects on the fish populations at certain times of the year. Only species able to cope with such unstable conditions survive. Lower reaches of rivers, which may not even be in the devegetated zone, experience a change in flow to seasonal instead of year-round. Spawning occurs in the spring for many species when abnormal runoff is often high and eggs may be washed away, smothered by silt or subjected to desiccation on recession of high water levels.

Devegetated areas are more susceptible to the action of wind. Rivers and streams of the Seistan basin are often blocked by sand blown by the 'Wind of 120 Days' such that they change course with major effects on the fish fauna (Anon., 1966). Increased surface runoff causes greater erosion, destroying stream habitats and the fauna and flora on which fish depend by washing them away, by siltation and abrasion. Direct effects on the fish themselves of turbid waters will also limit species and abundance in streams subject to excessive erosion. Certain species are not able to respire effectively, locate food or mates, or carry out reproductive behaviour under such conditions. Erosion also lowers the water table so that springs, marshes and their associated streams dry up. This is a particularly serious loss of habitat for those fishes which use such waters as refuges from the torrential regimes of larger streams and rivers. Lowered water tables cause rivers to be intermittent for part or most of the year. Personal observations have shown that this severely restricts the abundance of fishes in a river system and survivors in isolated pools are typically emaciated.

Irrigation

Extensive irrigation projects were undertaken in many parts of Iran under various dynasties and date back as early as the third millennium BC, forming extensive habitats for fishes and perhaps replacing to some extent the swamp habitats first drained and settled as early as Babylonian times in Mesopotamia. However, wars, invasions such as that of the Mongols in the mid-13th century, and neglect perhaps aggravated by variations in flow of rivers resulted in destruction of these irrigation networks and although many were reconstructed they cannot be regarded as stable habitats.

Khuzistan has long been characterised as a desolate waste largely taken over by silt from river floods and wind erosion but remains of ancient irrigation canals and dams can be seen in this province. Irrigation brings with it the danger of soil salinisation through surplus water infiltered into the soil causing a rise in saline groundwater or through slightly saline water evaporating when dammed. Many freshwater fishes have a low tolerance of salinity and runoff from such soils might well increase salinity in smaller water bodies to critical levels. Records of soil salinity problems in southern Mesopotamia date from 2400 BC (Whyte, 1961).

An important source of irrigation and general purpose water throughout much of Iran for more than 25 centuries has been the qanat or ghanat, described in detail by Smith (1953) and Beaumont (1974). A qanat is basically a gently sloping tunnel located in alluvial fans of foothill regions where it taps the water table at a depth of 20 to 250 m to provide a continuous discharge by gravity flow at the lower end of the tunnel. Vahidi (1963) maintains that there are 50,000 qanats in Iran, ranging in length from a few hundred metres to as much as 50 km, and with a total discharge exceeding Iran's largest river. Construction of qanats is expensive and time consuming and both maintenance and the initial construction process are dangerous because of the unstable nature of alluvial fan material. The qanat and its stream are an important refuge for fishes, providing a constant flow of water of consistent temperature and, within the qanat itself, protection from insolation and predators. In some areas of Iran there is little surface water for fishes, apart from the qanat. 'Mining' of groundwater by qanats often led to a reduction in flow such that they had to be lengthened, thus penetrating deeper into the alluvial fan. Eventually longer qanats were abandoned for economic reasons as were those that collapsed or were destroyed in wars. Although qanats provide habitats for fishes they do lower the water table so that nearby springs and streams dry up. Subsequent loss of a series of qanats for the reasons outlined above would then eliminate the fish fauna of an area.

Natural water level fluctuations

There are historical records of water level fluctuations in such basins as the Caspian and Seistan which are not explicable solely on the basis of devegetation since there have been both rises and falls in water level. These basins receive much of their water from large catchment areas in other regions with a different topography and/or climate. Their water levels were therefore dependent on rainfall levels outside their immediate surroundings. Dunin-Barkovsky (1977) records level fluctuations of up to 50 m in the Caspian Sea for the Holocene period due to variations in the general moistening of Eurasia and intermittent warming and cooling variously associated with changes in precipitation and evaporation. Brooks (1949) contends that the Oxus (Amu-darya River) flowed into the Caspian in the 14th century instead of into the Aral Sea. Shnitnikov (1969) records flow along the Uzboi channel into the Caspian from the Aral Sea at several periods, namely at the end of the third millennium BC, at the turn of the second millennium BC, in the end of the first millennium BC, and in the 14th to 16th centuries AD. Glubb (1967), however, maintains that the Oxus changed its course in 1220 AD, discharging into the Caspian Sea when the Mongols cut its banks after the capture of Urganj. Brooks (1949) also records high lake levels in Seistan about AD 900. Gholizadeh (1963) records drought years from 1957–62 for Tigris, Euphrates and Karun Rivers and their tributaries and such conditions no doubt occurred in pre-industrial times. Variations in rainfall, snow cover and insolation are marked in many parts of Iran. Several 'wet' or several 'dry' years in succession can affect surface water levels and groundwater recharge.

INDUSTRIAL FACTORS

This section covers those factors affecting fish distribution and abundance which have become most prominent in the last 50 years as concomitants of industrialisation and a burgeoning population.

Devegetation

Although devegetation is a process of prehistorical and historical age, it still continues today. Perennial and annual vegetation is cut and carried by hand for fuel and Whyte (1961) has recorded motor vehicles radiating out from Tehran in a search for fuel, making devegetation more extensive and complete. It is calculated that 10,500 ha of plants, numbering perhaps 105 million shrubs, were uprooted in 1977 for Chahar-Shanbeh Suri, when these plants are burned as part of the Persian New Year celebrations (*Kayhan International*, 9 May 1978). The economic dislocations attendant on a change in government through revolution in 1979 have resulted in felling of trees for fuel (*Manchester Guardian Weekly*, 12 August 1979).

Dorst (1970) reports statistics for Iran based on data published in 1960 that cite 27 million sheep, 12 million goats and 5·24 million cattle, while the carrying capacity of the country was then equivalent to 26 million sheep. For administrative, social and economic reasons it was not possible to reduce the numbers of animals with any rapidity.

Firouz (1974), writing on the Zagros and other forests outside the Caspian area, states that less than one-tenth remains compared to pre-Second World War levels. Logging on very steep slopes and right up to the stream bed in the Caspian basin is being carried out according to Razivi *et al.* (1972). Stream water is warmed when tree cover is removed and this has proved harmful to native and migratory fishes. The stream becomes choked with debris and oxygen levels fall as this organic material decays.

Other consequences of vegetation and forest destruction and excessive numbers of grazing animals for the environment including fish habitats have been described previously.

Water abstraction

A burgeoning population, construction of many industrial complexes and the needs of agriculture have led to a greatly increased demand for water. Evaporative coolers are now widespread household fixtures and these consume very large quantities of water (Beaumont *et al.*, 1976). Deepwell pump installations now compete directly with qanats for limited groundwater (Vahidi, 1963) and owners of qanats prefer to drill wells rather than maintain or extend drying qanats (Mandel, 1975), and perhaps 25% of qanats in Iran are now non-functional. Unlike qanats, wells do not support a fish fauna. Excessive demands on groundwater of a region by numerous wells might also lead to drying up of marsh and spring habitats. Channelisation of rivers converts a natural environment replete with vegetation cover and food organisms into an artificial environment with few of these essential requirements for maintenance of fish populations.

Construction of dams has been a feature of the Iranian industrialisation programme, twelve having been completed and a further six being under construction or at the planning stage (Beaumont, 1974) (Fig. 1). Dam construction

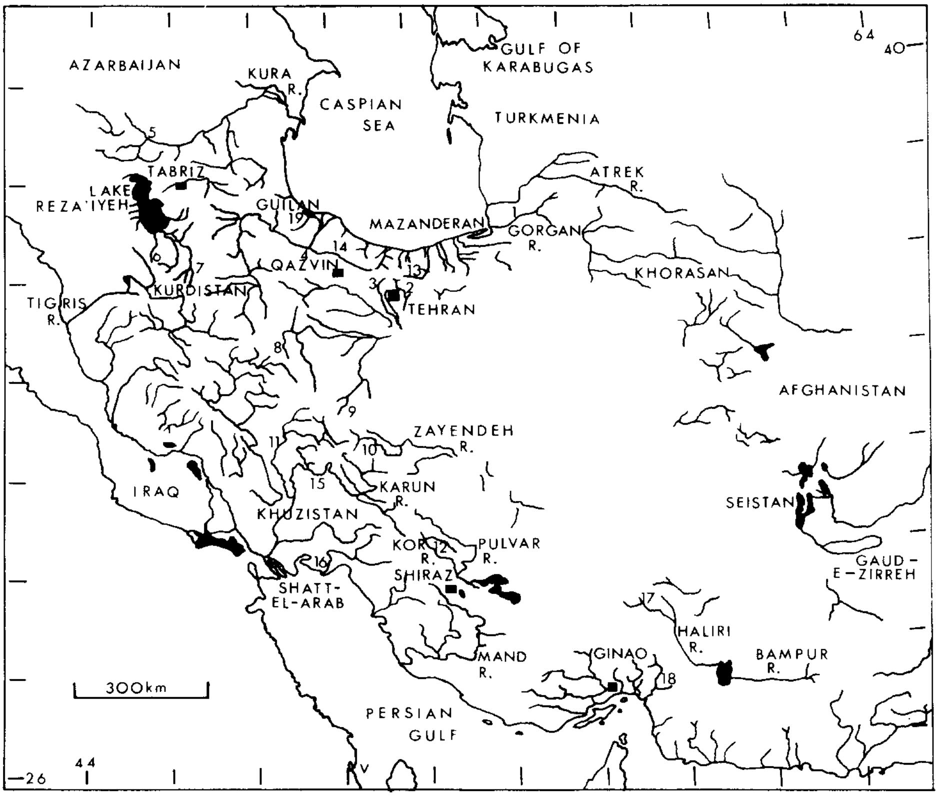

Fig. 1. Map of Iran to show major drainages and dams. Dams are numbered 1–18, the first 12 are completed and the last 6 are proposed or under construction (1 = Sangarsavar on the Gorgan River, 2 = Farahnaz on the Jaji River, 3 = Amir Kabir on the Karadj River, 4 = Shahbanou Farah on the Sefid River, 5 = Aras on the Aras River, 6 = Shapur Aval on the Mahabad River, 7 = Kourush Kabir on the Zamreh River, 8 = Shahnaz on the Karachai River, 9 = Shah Esmail on the Qom River, 10 = Shah Abbas Kabir on the Zayendeh River, 11 = Mohammed Reza Shah on the Dez River, 12 = Dariush Kabir on the Kor River, 13 = Lar on the Lar River, 14 = Talegan on the Shah River, 15 = Reza Shah Kabir on the Karun River, 16 = Nader Shah on the Marun River, 17 = Jiroft on the Haliri River, 18 = Minab on the Minab River). 19 = Pahlavi Mordab.

affects fish populations in many ways. Even before completion the construction of a dam may cause heavy loads of silt to be transported down river with adverse affects on the fish fauna (Anon., 1972). Dams may accelerate the fall of the water table by blocking recharge of groundwater through the absence of floodwaters. Fishes which normally breed in flooded areas each spring can no longer do so. The river below the dam has its flow regime altered by power and irrigation requirements and large quantities of deoxygenated, hot surface or cold bottom water may be poured abruptly into the river from the dam. Construction of the Dorudsan dam on the Kor River near Shiraz has led to the loss or reduction of marshes down river (Cornwallis, 1968). Gas-bubble disease may occur in down-river fishes which ingest water supersaturated in gases caused by turbines, or when air bubbles are carried to great depths over a spillway where pressure forces gas into solution. Migration is physically prevented by dams even though fish ladders are constructed (Dorst, 1970). Dams are not the only barriers to fish migrations. Highway bridges in the Caspian basin often have a weir underneath them constructed in such a fashion that migrations are difficult or impossible even during periods of high flow (Razivi *et al.*, 1972). Migrating fish become delayed by dams and this leads to degeneration of eggs, so that entry into a fish-passing device occurs with reduced or lost fecundity. Also the concentration of fish, eggs and larvae in reservoirs or below dams leads to loss by predators. Reduction of flow will also interfere with migrations. Vladykov (1964) has noted that dam construction on the Sefid River made no allowance for requirements of spawning sturgeon from the Caspian Sea. Water flow was reduced and shallow river water became overheated, leading to the death of such food items as aquatic insects and crustaceans on which young sturgeon depend. Many adult sturgeon were attracted into irrigation channels by their strong water flow and ultimately perished. Still water in the dam caused silt deposition and increased river water transparency. Silt particles in the river water are an essential condition for successful reproduction of sturgeons. Also predators are more effective in clear water (Baxter, 1977). Dams often trap sediments and nutrients to the detriment of the down-river environment. In a devegetated country like Iran, dams rapidly silt up because of erosion on the bare surrounding hills. Life expectancy of such dams as the Shahbanou Farah and Mohammed Reza are low (Beaumont, 1974; Khodjeini & Mohamed, 1975). The reservoir which forms behind a dam alters the aquatic environment from a stream or river to a lake, and fishes are often ill-adapted for such a change. Construction of a large earthfill dam on the Lar River in northern Iran will convert 40 km of stream habitat ideal for trout spawning into still water and end fishing there.

Introduction of new species to exploit the sport fishery potential of the reservoir brings with it certain dangers for native species throughout the river basin. These dangers are outlined more fully later but certain points can be given here. The newly stocked reservoir initially shows high yields based on cover and food supply provided by drowned vegetation, but several decades of poor yields occur as the vegetation is exhausted or covered by silt until settling of plankton produces a new organic layer. The reservoir is subject to abrupt fluctuations in water level according to the needs of water or electricity consumers, and under such conditions rooting aquatic plants and stable shore habitats for reproduction and growth of fishes cannot develop. Parasite infestations can become high in reservoirs because more zooplankters are available as intermediate hosts (Baxter, 1977).

Certain areas of Iran depend on water supplies from neighbouring countries. The prime examples are the endorheic basins of the Caspian Sea, which receives 76% of its water from the Volga River in the USSR (Zenkevitch, 1963), and the Seistan lakes fed by rivers, principally the Helmand or Hirmand, which flow from the mountains of Afghanistan. Fifty per cent of the waters of the Volga are controlled by dams resulting in a serious fall (nearly 3 m between 1930 and 1962) in the level of the Caspian Sea, with profound repercussions on fish habitats (Micklin, 1979). In addition an increase in salinity has occurred, notable in northern sections, adversely affecting the biomass of benthos which constitutes a substantial part of fish food (Vladykov, 1964). The Russian sturgeon fisheries have declined by 50% since 1913 (Dorst, 1970). However, it is principally the shallow northern Russian parts of the Caspian which are affected and the steeper Iranian shore offers some protection against habitat loss if the fall in level is gradual, giving time for new areas to develop. Prehistorical and historical natural water level fluctuations have been noted above, which the fish fauna appears to have survived. In modern times there is additional pressure on the fauna from fishing and pollution and the decline in level is likely to be continuous unless corrective measures are taken. While species survival is probable there is a definite decline in catches of commercially important species which Vladykov (1964) attributes to a falling Caspian Sea level. In the 1930s the Pahlavi Mordab, a lagoon area of the Iranian Caspian shore, was 4–8 m deep but in the 1960s it was only 1 m deep, muddy and weed-choked. Such conditions led to oxygen deficiencies through plant respiration and fish mortalities occurred. Spawning areas were rendered unsuitable and migratory fishes were obstructed. Catches for four commercial species declined from 6682 tonnes in 1933/34 to 319 kg in 1961/62. Fall in Caspian Sea level has drained marshes along the whole length of the Caspian lowlands and many areas have been drained for agriculture resulting in a loss of aquatic habitats. The Gulf of Karabugas concentrates Caspian Sea salt by evaporation, preventing a rise in salinity despite a daily input to the Sea of $17{\cdot}7 \times 10^7$ kg of salt. If the level of the Caspian falls too low to maintain flow into the Gulf then the Caspian salinity will rise to harmful levels.

Two of the Seistan lakes, Hamun-e-Hirmand and the Hamun-e-Sabari, were largely dry in the winter of 1976 because their main water source, the Helmand River, was restricted by the Kajaki dam in Afghanistan. Hamun-e-Pazak, fed by the Khash River, was in good condition at this time. These Seistan lakes retain a freshwater character despite being an endorheic basin because floods and the seiche resulting from the 'Wind of 120 Days' spill water through a channel to the Gaud-e-Zirreh, a salt flat in Afghanistan. The Kojaki dam and the Kohak and Zehak barrages in Iran, if they do not lead to complete drying up of these lakes, may well lead to an increase in salinity in the absence of a flushing effect, with eventual deleterious effects on the fish fauna.

Many areas of Iran are threatened by water loss, ironically because of irrigation schemes, for example, Lake Kobi and the Ghara Gheshlaq marshes of Azarbaijan, which understandably take priority over preservation of habitats when there is an increasing population to feed. Discharge of the Tigris-Euphrates system decreased in 1957–62 in part because of increased use of water for irrigation in Iraq

(Gholizadeh, 1963). In addition, lack of proper drainage of irrigation water and inadequate drainage of flood waters, coupled with high evaporation, have increased soil and water salinity (Anon., 1961), for example, salt content of Iraq drainage channels into the Arvand River (= Shatt-el-Arab) on the border with Iran was recorded as 40,000 ppm, of which 70% was sodium chloride (Gholizadeh & Fatemi, 1969). Water abstraction from many Caspian streams for rice growing helped to deplete severely stocks of the Caspian 'salmon' or mahi azad, *Salmo trutta caspius*, which requires a fast current for spawning. The streams became shallow and weed-choked, the current slowed and water temperatures rose above the tolerance level for mahi azad. Sefid mahi, *Rutilus frisii kutum*, the most popular Iranian food fish, is also susceptible to such changes in the environment, particularly in spawning areas (Vladykov, 1964). Demand for water is so great during June–September in the Caspian lowlands that many rivers are drained completely. Razivi *et al.* (1972) estimated that over 90% of the coastal Caspian streams were dry in July. Late summer spawning of *Barbus brachycephalus* and *Aspius aspius* is prevented and many larvae of spring spawners are lost when they enter irrigation canals and become stranded in fields.

Fishing

Sport fishing is still of only minor importance in Iran outside high, cool mountain trout streams and lakes. Certain cyprinid species are caught by local people using extensive gill nets, but this is not carried out on a commercial scale except to a minor degree in some rivers of Khuzistan, Guilan, Mazanderan and the Seistan lakes where fish are sold locally.

Poaching has been a cause of a decline in catches of sefid mahi in the Pahlavi Mordab. Ralonde & Walczak (1972) consider poaching to run rampant, 'One merely has to ride up one of the exit streams of the Mordab any time of day to find the rivers almost completely blocked for migratory fish passage during the late winter and spring migratory periods.' Heavy poaching of sturgeon occurred in Caspian waters as the country underwent a revolution in 1979 when normal efforts to control this problem were not effective (*Manchester Guardian Weekly*, 12 August 1979).

The once commercially important Caspian 'salmon' was almost driven to extinction by excessive use of nets, traps and even dynamite in the late 1950s (Firouz, 1974). The introduction of synthetic fibre gill nets in 1957 led to an increased yield of Caspian Sea sturgeons while the fall in sea level apparently did not have a great effect on sturgeon fisheries (Vladykov, 1964). Yearly catches by seines of non-sturgeon species in the Iranian part of the Caspian Sea, such as *Rutilus frisii kutum*, *Rutilus rutilus caspicus*, *Cyprinus carpio*, clupeid species, *Mugil* and *Liza* sp., *Stizostedion lucioperca* and *Silurus glanis*, have declined drastically, the 1961–62 catch being less than one-tenth that of the 1956–57 catch. The average production for the years 1927/28–1931/32 was 9497 tonnes, declining to 4469 tonnes in 1952/53–1956/57 and to only 821 tonnes in 1957/58–1961/62. This may be due in part to overfishing but changes in the environment are undoubtedly major factors. Fall in Caspian Sea level severely affected the major fisheries in the Pahlavi Mordab as was outlined above.

Pollution

Pollution of freshwaters in Iran is not a new concept since the Zend Avesta contains precepts guiding the disposal of waste. However, as Yazdani (1973) pointed out, water pollution was not a major problem before 1960 because of the underdeveloped state of industry and agriculture. Visual (and nasal) evidence of water pollution is now apparent in many parts of Iran. Human wastes are discharged untreated into the ground or into the nearest water course in many cities. The effects of sediment from erosion of unprotected soils and overgrazed pastures have been noted above as have the dangers of salinity and choking of habitats by aquatic vegetation. Dorst (1970) has briefly reviewed in general pollutants and their effects on freshwater and fishes. A few examples from Iran will here suffice to delineate the problem.

The prime cause of pollution in the coastal Caspian region is urban waste. There are about 70 towns in this area out of a total of about 240 in Iran, many of them are on the waterfront and almost all lack a proper sewage system (*Kayhan International*, 8 March 1978). Pesticides used in agriculture, industrial wastes, and petroleum and oil from the oilfield of Baku Bay, USSR are also a problem in this region (Firouz, 1974; Hollis, 1978). Griffiths *et al.* (1972) report a million-litre kerosene tank spill in Rasht that flowed to the sea via the Pahlavi Mordab. Similar accidents must also be expected in the future. A fish kill in the Gorgan River in 1978 was attributed, according to local informants, to careless insecticide spraying on adjacent fields. Newspaper and radio reports variously stated that some 200 barrels of a highly toxic chemical spilled into the river when a truck overturned and that the chemical, identified as Turbidan from the Trintext chemical plant, was dumped by a technician commissioned to get rid of the waste product (*Kayhan International*, 7 May 1978). Savage & Firouz (1968) have reported that marshes along the Atrek River of this region were polluted and also the river systems feeding the Khuzistan marshes in southern Iran.

The jube system, a series of channels carrying water along the streets of most Iranian towns and cities, is also a source of pollution. It functions to irrigate roadside trees but also serves to carry away detergents and other pollutants which may be poured into the nearest river or stream. The Khoshk River in Shiraz is little more than an open sewer in the summer and autumn, receiving jube water and other untreated urban wastes.

A fish kill, numbering in the many thousands, occurred in the Mand River near Shiraz in 1977 and was attributed to chemicals used in spraying against malarial mosquitos. The people hired to spray village houses either dumped quantities of the chemical into the river to reduce their work load or washed out containers in the river. The Pulvar River, north of Shiraz, was polluted in 1978 with wastes from a food factory and other buildings and a fish kill was reported. The Barm-e-Dalak marsh near Shiraz has recently been used as a dumping ground for various industrial wastes, depleting the fish population by habitat destruction and water pollution. Urban wastes from the village of Kavar on the Mand River south of Shiraz are poured into the river. During periods of high water flow in winter and spring this pollution is diluted but it becomes very obvious during low water flow in summer months when, in addition, water is abstracted upriver for irrigation of farm land. A section of the river is fishless because of the pollution below Kavar.

Fertilizers were first used in Iran on a large scale in 1956 when 3000 tonnes were imported. By 1969 250,000 tonnes were being used and must have affected the aquatic environment through runoff.

Introductions

Introductions or faunal supplementations using fishes can be of great utility but may also be a hazardous undertaking for a number of reasons. Exotic fishes from another continent or from a different drainage basin may introduce a disease or parasite to which native fishes are ill-adapted thus causing a drastic reduction in the population. Exotics may prove to be serious predators or competitors of indigenous fishes. They may become distributed outside their carefully chosen river or lake, through the agency of anglers, into areas where their potential effects have not been gauged. Adequate studies to determine that the proposed introduction will be beneficial can be very expensive (Hubbs, 1977) and are seldom carried out by cost-conscious authorities. There are several active and completed introduction programmes for fishes in Iranian waters and some of these are discussed individually by species below. However, before describing these deliberate introductions, the danger of accidental introductions by water diversion schemes should be outlined.

The headwater streams of the Karun River system (draining to the Persian Gulf) have been diverted into the headwaters of the Zayendeh River (an endorheic basin) for industrial expansion and the needs of agriculture in the Isfahan area since 1953. The headwaters of the Lar River, a Caspian tributary, may be diverted into the Jaji River via a tunnel beneath the Elburz mountains to augment Tehran's water supply. Fishes might not survive tunnel travel and diseases or other unsuitable organisms might become established outside their normal range. So little is known about the ecology of freshwater organisms in Iran that the dangers, or lack of them, cannot be assessed. Continued economic growth in Iran will depend on large-scale transfer of water in this fashion since abundant water is concentrated in the north and west of the country (Beaumont, 1974).

Diversionary schemes and transport canals outside Iran may affect the Iranian fish fauna. The Volga-Don canal connecting the Caspian Sea and Azov Sea was completed in 1954–55 and may well result in Mediterranean euryhaline elements reaching the Caspian Sea. Fish populations are not only threatened by exotic fishes but also by introduction of other organisms. Zenkevitch (1963), for example, has described how a bivalve mollusc, *Mytilaster lineatus*, was accidentally introduced overland into the Caspian Sea from the Black Sea on the underside of small boats during the civil war (it can survive transport out of water with its valves closed). It was first recorded in 1928; by 1933 on the eastern shore of the southern Caspian it comprised 18% of the total benthos biomass, and is now more than 90%. It suppresses development of fish food items, in particular another bivalve *Dreissenia*, but also forms part of the diet of such commercially important species of fish as uzun burun *Acipenser stellatus* and sefid mahi *Rutilus frisii kutum*.

The projected diversion of Arctic flowing rivers, and the use of water from Lakes Ladoga and Onega and from the Sea of Azov to renew and stabilise Caspian Sea water level may well introduce predators, parasites, diseases or habitat destroyers (Zenkevitch, 1963; Kovda, 1961; Hollis, 1978; Micklin, 1979).

The following are the principal supplementations in the fish fauna of Iran:

Gambusia affinis. The mosquito fish has been actively distributed throughout Iran as part of a successful effort to combat malaria. It has the dubious distinction of being the most widely distributed and one of the most numerous fish species in Iran. *Gambusia* eat the larval mosquitos which develop in fresh and brackish waters and which as adults are vectors of malaria. There are two subspecies of *Gambusia*, *G. affinis holbrooki* which is found throughout Iran, and *G. a. affinis* which is said to be limited to Caspian drainages. *Gambusia* was first imported to the Ghazian marshes of the Caspian littoral from Italy during 1922–30. Its original distribution is in southern North America and Central America. An extensive campaign was mounted, starting in 1966, to distribute *G. a. holbrooki* throughout Iran to over 3000 permanent water bodies (Tabibzadeh *et al.*, 1970). The original source was the Ghazian marsh but natural waters in other parts of Iran are being used as reservoirs for stocking surrounding areas. It is quite possible that young, indigenous fishes may be inadvertently distributed outside their natural range along with *Gambusia*.

Observations in other countries have shown that introduction of *Gambusia* is destructive not only to fish of similar and smaller sizes but also to larger fishes since *Gambusia* will eat their eggs and young (Berg, 1948–49; Menon, 1965). *Gambusia* should not be introduced to newly constructed reservoirs because it competes for food with various cyprinids (Nikol'skii, 1961) which are of potential economic and recreational importance throughout Iran. Competition and predatory activity between *Gambusia* and native Iranian fishes has not been investigated and it is now ineradicable from Iranian waters. Its effectiveness against mosquito larvae is not disputed when used in conjunction with insecticides but there are several, native Iranian species whose effectiveness as mosquito destroyers could have been tested. These include the cyprinodont fishes of the genus *Aphanius* which has four species in Iran. Two of these, *A. dispar* and *A. sophiae*, have been shown to eat mosquito larvae, at least under experimental conditions (Al-Daham *et al.*, 1977), have an annual life cycle, a high tolerance of temperatures and salinities and are widely distributed in diverse fresh and brackish waters over southern Iran (personal observations, 1976–78), making them suitable candidates for introduction to control mosquitos. In more northerly waters other native species could conceivably be used for malaria eradication programmes. Berg (1948–49), for example, has noted that *Cyprinus carpio* fry regularly consume mosquito larvae. However, care must be exercised in introducing such a species outside its normal range as adult *C. carpio* destroy water plants, eat the eggs of other fishes and muddy the water, rendering it unsuitable for other more sensitive species. Species of *Gobio*, *Alburnoides*, *Varicorhinus*, *Alburnus*, *Noemacheilus* and *Pungitius* are also reported to be useful in mosquito control and these genera are found in Iranian waters (Dubitskiy & Rusinov, 1971; Dubitskiy & Abdil'dayev, 1975).

Salmo gairdneri, *Salmo trutta*, *Oncorhynchus keta* and *Coregonus lavaretus*. The rainbow trout, *S. gairdneri*, has been introduced extensively into suitable, high, cool, lakes and streams of the Elburz and Zagros mountain ranges since about 1966 (MacCrimmon, 1972; Firouz, 1974), and in such reservoirs as Amir Kabir, Shahbanou Farah, Mohammed Rez Shah and Latian (Surber, 1969). Since 1973 almost two million fingerlings have been introduced into 20 locations, many of which were previously fishless. Breeding populations are now established in some rivers (Walczak, 1972), such as the Gahar Lake and its outlet stream, Dez River drainage and the Ab-e-Bazuft (Saadati, 1977). This species is native to western North America.

The mahi azad, *S. trutta caspius*, is found chiefly in the Lar and Karadj Rivers outside the Caspian basin. Stocks in the former may well disappear or be severely depleted by construction of a dam. Some introductions to other suitable habitats have been made. The Lighvanchai brown trout, possibly a subspecies distinct from the European brown trout and the mahi azad, is isolated in the Lake Reza'iyeh basin and attempts are being made to transplant breeding stocks to other parts of Iran to prevent its extinction. In 1975, 500 specimens were introduced into the Ab-e-Bazuft River near Shiraz. European brown trout *S. trutta trutta* have become established in the Zagros Mountains south of Dorud.

The chum salmon, *O. keta*, is found in the Caspian Sea, fry having been released from the Samur Fish Farm in Dagestan, USSR during 1962–1967 (Magomedov, 1970).

The whitefish, *Coregonus lavaretus*, was introduced as fingerlings into the Karadj and Latian Reservoirs during 1965–1967, but apparently did not become established in the Latian Reservoir and Walczak (1972) reports only a small population in Karadj Reservoir. There was no evidence of reproduction. Saadati (1977), however, refers to these populations being 'established'.

Large salmon and trout are potential predators on other fishes as well as being possible disease or parasite carriers like the whitefish. Particularly dangerous from the infestation angle are exotic species like *S. gairdneri* from another continent.

Introduced salmonids may also compete for food and spawning grounds with native salmonids and with other fish species. MacCrimmon (1972) reports the rainbow trout from the Ligranchay River (? = Lighvanchai) of Azarbaijan and from Caspian Sea rivers which have native populations of trout.

Mugil and *Liza* species and *Pleuronectes flesus luscus*. Between 1930 and 1934 three species of mullet (*L. auratus* chiefly but also *L. saliens* and *M. cephalus*) were transplanted from the Black Sea to the Caspian Sea by Russian authorities and are now caught in commercial quantities (Berg, 1948–49; Vladykov, 1964). Deleterious effects of these species, and of *Pleuronectes* introduced in 1902 and 1931, on local fishes have not been reported. Large *Pleuronectes* feed on fish however.

Stizostedion lucioperca and *Esox lucius*. These two predatory sport fishes are native to Caspian drainages but are being introduced into reservoirs and lakes outside their normal range, e.g. Valasht Lake near Marzanabad in Mazanderan, Evan Lake near Qazvin, Ghorigol Lake near Tabriz, Marivan Lake in Kurdistan and the Haft Barm Lakes west of Shiraz among others. Both these fishes feed almost exclusively on other fishes when adult. They also carry *Diphyllobothrium latum*, a tapeworm, as cysticerci in their muscle tissue. *Diphyllobothrium* attains its adult form in man through consumption of poorly cooked fish (Nikolsky, 1963; Bykhovskaya-Pavlovskaya, 1964).

Ctenopharyngodon idella and *Hypophthalmichthys molitrix*. The grass carp, *C. idella*, may become established in Iran where experimental stations are testing its utility in pond fish farming and for excess aquatic vegetation control. It was introduced into the Pahlavi Mordab on the Caspian littoral and survived until at least 1967 but did not appear to be reproducing (Armantrout, 1969). 50,000 grass carp fingerlings from the USSR were released into the Caspian Sea and Pahlavi Mordab in October 1970 (Griffiths *et al.*, 1972) and this species has been introduced into canals of the Dez Irrigation Project, Khuzistan. The native range of grass carp is the Amur River basin of the far eastern USSR and there is danger of introduction of exotic diseases and parasites. A tapeworm, *Bothriocephalus gowkongensis*, has become a serious problem in European cyprinids which became infested via introduced grass carp (Courtenay & Robins, 1975). Reduction of submerged vegetation, while initially helpful in overgrown areas, can increase vulnerability of other species to predators and deprive them of spawning or feeding habitats.

The silver carp, *H. molitrix*, another far eastern cyprinid, was found in 1974 in the Pahlavi Mordab, probably as a result of a private fish farming enterprise or from Soviet Union stocks in the Caspian basin (Saadati, 1977).

Both these species are being introduced into Russian Azarbaijan and Turkmenia which have drainages in common with Iran (Abdurakhmanov & Abbasov, 1973; Aliev & Sukhanova, 1974). Any attendant dangers are not therefore under the immediate control of Iranian authorities.

Crasssius auratus. The goldfish has become established in certain Iranian waters, notably the Hamun-e-Seistan, presumably as discarded aquarium fish. This species tends to muddy waters which may then be of less than optimum condition for other species.

Pimephales promelas. A fathead minnow population exists in a reservoir south of Tehran. It was introduced accidently with large-mouth bass and bluegills (see below). This North American cyprinid is a potential source of infestation with exotic diseases and parasites.

Micropterus salmoides and *Lepomis macrochirus*. The large-mouth bass, *M. salmoides*, is a North American predatory fish introduced into certain Iranian waters, e.g. the Ardakan-Yasuj area of the southern Zagros north of Shiraz (A. Shiralipour, pers. comm. 1978). Apart from dangers of truly exotic diseases and parasites this species is a marked predator on other fishes. Large-mouth bass and bluegills (*L. macrochirus*) from N. America stocked in the Yengi-Kand reservoir south of Tehran (Andersskog, 1970) all perished from winterkill (R. J. Behnke, pers. comm., 1979).

CONSERVATION SCHEMES

The freshwater ecosystems of Iran are endangered because of rapid industrialisation, an increasing population and an environment degraded since prehistorical and historical times coupled with a shortage of water. As noted in the Introduction there is no tradition of concerned naturalists to agitate for environmental protection and such protection devolves on a government committed to massive industrial expansion. Mass-communication is being used to inform the public of environmental problems and appropriate methods of utilisation of natural resources. This is undoubtedly hampered by a high illiteracy rate, particularly in rural areas. Implementation of conservation schemes is held back by a lack of skilled, responsible and concerned workers. Training programmes are being used to alleviate this shortage but without widespread popular concern for conservation of natural resources trained manpower will remain overextended. Very few Iranians could have been aware of the 'Pahlavi Environmental Prize' ($50,000) which was awarded annually on an international basis by the Government of Iran for the most outstanding contribution in the field of the environment. Also the recent change of government calls into question the emphasis that will be placed on conservation in the future. Some of the impetus for environmental studies in Iran was provided by foreigners (witness the senior authors of recent books on mammals and birds) and it is to be hoped that this will not be viewed as 'westoxication'. Many efforts are being made and some of these are outlined below.

Biotic reserves and legislation

Iran has 70 biotic reserves aggregating to a total area near to 8 million ha (Anon., 1977–78). Firouz (1976) and Firouz & Harrington (1976) give details of general conservation schemes in Iran which will benefit the fish fauna. Emphasis has been shifted from protection of individual species to protection of the different types of ecosystems to be found in the country. While this is undoubtedly a valid idea for such comparatively well known vertebrates as mammals and birds, the fishes are not well enough known to ensure that all species and lower taxonomic categories are adequately protected. A detailed survey, with special emphasis on endangered waters, should be made to ascertain the distribution and status of the fishes. Taxonomic revisions should also be made to clarify the systematics of Iranian fishes so that a proper appreciation of the species content of the fish fauna is available. At the moment there are not even keys for identification of Iranian freshwater fishes outside the Caspian basin.

Fines of 10,000 rials (approx. US$140) are levied for illegal capture of mahi azad *Salmo trutta caspius* and cave fishes *Iranocypris typhlops* and *Noemacheilus smithi* and fines and terms of imprisonment are penalties for fishing during unlawful seasons or hours, for fishing by unlawful methods or without a licence, and for destruction of vegetation in a biotic reserve. It would require a considerable expansion of staff for the Department of the Environment to patrol all waters effectively, however, given the size of the country.

The government has banned all private well-drilling in the Varamin plain without a permit to control the drain on groundwater resources.

Afforestation, soil stabilisation and grazing management

Afforestation programmes are being carried out in many parts of the country although these are hampered by a lack of water on dry mountain slopes. Since 1967, 12,000 ha of forest plantation have been established and almost 70,000 ha of desert land seeded or planted (Mehdizadeh, 1971*a*). These figures should be compared with the area set aside as biotic reserves.

Research is being carried out in the field of soil stabilisation by mulch, 2–3000 ha having been stabilised in this manner, as well as selection of appropriate species of vegetation to prevent erosion. Watershed management is being undertaken over the catchment area of dams to prevent excessive erosion and siltation. Extensive studies have been made on selection of shrubs for burning at New Year celebrations and on cost evaluation for marketing cultivated and wild shrubs in an effort to reduce devegetation.

Substitution of petroleum fuels, such as kerosene, is helping to prevent devegetation. The number of cooperatives for the distribution of fuels rose from 28 in 1964 to 8000 in 1970. New methods are being used for more efficient charcoal production (Anon., 1961).

Research on management of grazing is being undertaken to best meet the needs of vegetation, soil, animals and owner (Mehdizadeh, 1971*b*).

Water quality

In 1967 Iran passed a law nationalising the water resources of the country and regulations exist for limiting discharge of pollutants into natural waters (Yazdani, 1973). The effective enforcement of such regulations could, however, be considerably improved.

Research and practical measures in a number of fields related to water quality are being carried out in Iran. These include siltation studies in most Iranian rivers, snow surveys to gauge runoff, rainfall and river gauging, flood control by dam construction; for example, the Reza Shah Kabir dam on the Karun River has been used to regulate flow so there is more freshwater in the river during the dry season and this assists in combating salt intrusion (Gholizadeh & Fatemi, 1969), rehabilitation and expansion of irrigation canals, surveys of underground water, and river retention dykes (Anon., 1961). In addition loans are made available for qanat construction and maintenance, and deepwells are dug in qanats to tap artesian water, thus prolonging use of the qanat.

Pesticides, industrial effluents and mining residues are being studied as to their effects on fish reproduction (Firouz, 1974).

Research on synthesis of biodegradable detergents is being carried out by the National Iranian Oil Company in an effort to prevent surface and groundwater pollution. Sewage systems are being constructed in many parts of Iran and are now compulsory for all towns on the Caspian littoral, for example.

A joint agreement was signed with the USSR in 1973 to combat pollution in the Caspian Sea (Firouz, 1974), and the USSR authorities have issued a special directive on 'Measures to prevent pollution of the Caspian Sea' which may aid the protection of fish stocks shared between the two countries.

Measures for fish conservation

A number of measures have been taken which directly help to conserve fishes in Iran. Fishing is controlled in an 8000-ha area of the Pahlavi Mordab set aside as a refuge (Firouz, 1968). Ralonde & Walczak (1972) report extensive poaching in the Mordab until 1964 when strict enforcement was employed. Enforcement after the 1964–65 season gradually slackened to a level where it 'is literally non-existent'. Fishing operations in the Sefid River area were suspended in 1962 for a five-year period in an effort to increase the spawning stock of sturgeons, mahi azad and sefid mahi. In Iranian waters since 1952 baiting of hooks with oil cloth or fish has been prohibited. These methods took large numbers of immature sturgeons (Vladykov, 1964).

An expected loss of 90 % of the trout in the Lar River after construction of a dam at Polur is to be offset by provision of artificial spawning grounds and introduction of coldwater fish which could give an annual catch of 50 tons. The Shah Ismail reservoir was stocked with edible fish to replace coarse fish.

The United Nations has given advice on a series of fish culture stations and hatcheries and on a National Centre for Fish Culture and Research (Surber, 1969; Andersskog, 1970). Species cultured on a small scale include *Rutilus frisii kutum*, *Rutilus rutilus caspicus*, *Cyprinus carpio*, *Abramis brama*, and sturgeons such as *Huso huso*, *Acipenser stellatus* and *Acipenser güldenstädti* (Mokhayer, 1972).

Mahi azad has been studied in a majority of Caspian streams to assess its status. Plans for artificial propagation have been implemented by the Northern Fisheries Company at Bandar Pahlavi. During 1969 about 200,000 eggs were hatched from which 70,000 fingerlings of 5 cm length survived. A number of streams with populations of this species were declared Protected Rivers and maintenance of the whole watershed attempted (Firouz, 1974). Fishing for mahi azad has been banned since 1956 (Walczak, 1972). The Lighvanchai brown trout has been transplanted, e.g. to the Ab-e-Bazuft River near Shiraz, in an attempt to prevent its extinction. This particular transplantation has apparently failed (B. Sanford, pers. comm., 1979).

Conservation measures have been carried out in Russian waters of the Caspian Sea and these may contribute to an increase or maintenance of stocks and species in Iranian waters. In 1967, for example, the Volga fish farms produced 32,079 million sturgeon fry and the Kura farms 13,035 million sturgeon fry (Mil'shteyn, 1969). Iranian waters may benefit in particular from the product of the Kura farms which lie in Russian Azarbaijan across the border from Iranian Guilan. Artificial propagation of beluga *Huso huso* is being carried out in Russian waters to offset the unfavourable spawning conditions engendered by the regulation of the Volga discharge. Tagging at fish hatcheries in the Volga-Caspian region showed that 21·1 % of the total number of yearlings were recaptured in the south Caspian Sea as opposed to only 6 % in the north Caspian Sea. Older fish reared in Volga hatcheries have also been caught in the southern Caspian Sea. A considerable number of beluga fished in Iranian territorial waters belong to stocks reproducing in USSR rivers (Filippov, 1976). Artificial propagation is also undertaken for *Stizostedion marinum* which is commercially fished off the Turkmenian coast adjacent to Iranian Mazanderan (Guseva, 1975) and for *Salmo trutta caspius* in the Kura River adjacent to Iranian Guilan (Kyazimov & Alekperov, 1975).

THREATENED FISHES

It is difficult to assess the status of certain Iranian freshwater fishes since they are known only from their original descriptions based on a few specimens from one locality. They may well prove to be synonymous with more widely distributed and better known species (Coad, 1979). Other species, presumed or known to be valid, are known only from a single river system or lake but this may be due to poor field data. Species restricted to a single river system or lake are more susceptible to extinction through habitat destruction or pollution than more widely distributed species, particularly in Iran where lakes and rivers can be quite small but of immense value as a water source for industry and domestic consumption. These limitations on status assessment apply particularly to the speciose families Cyprinidae, Cobitidae and Gobiidae.

Miller (1972) has classified fish populations from a conservation standpoint and the following definitions are based on this work:

Endangered:	actively threatened with extinction. Continued survival unlikely without the implementation of special protective measures.
Rare:	not under immediate threat of extinction, but occurring in such small numbers and/or in such a restricted or specialised habitat that it could quickly disappear. Requires careful watching.
Depleted:	although still occurring in numbers adequate for survival the species has been heavily depleted.
Indeterminate:	apparently threatened on the criteria above but insufficient data currently available on which to base a reliable assessment of status.

The status of each species is assessed for Iranian waters only and species may be common elsewhere. A check-list of Iranian freshwater fishes is given in Appendix 1 so that the threatened fishes can be placed in context. A number of new species are referred to by various authors in the literature but since detailed formal descriptions are not available these are not referred to here. An undescribed species of cichlid is mentioned as this adds a new family to the fauna.

Family 2. Acipenseridae

2. *Acipenser güldenstädti*. Depleted.
3. *Acipenser nudiventris*. Depleted.
4. *Acipenser persicus* (regarded as a subspecies of *A. güldenstädti* by some authors). Depleted.
5. *Acipenser stellatus stellatus* natio *cyrensis*. Depleted.
6. *Huso huso caspicus*. Depleted.

These five species of sturgeons are found in the south Caspian Sea and tributary rivers. Overfishing (adults taken in spawning condition for their eggs which constitute caviar), pollution and habitat destruction, particularly of spawning grounds in rivers, have caused a decline of these species, at least on a commercial scale (Vladykov, 1964).

Hardly any rivers on the Iranian coast suitable for *Huso* spawning have been preserved apart from the Gorgan and Sefid Rivers which are now regulated. Conditions are generally unfavourable for natural reproduction of *Huso* (Filippov, 1976).

Family 3. Clupeidae

7. *Alosa brashnikovi*.	Depleted.
8. *Alosa caspia*.	Depleted.
9. *Alosa curensis*.	Indeterminate.
10. *Alosa kessleri*.	Depleted.
11. *Alosa saposhnikovii*.	Depleted.

12. *Clupeonella delicatula.* Depleted.
13. *Clupeonella engrauliformis.* Depleted.
14. *Clupeonella grimmi.* Depleted.

These eight species of herrings are fished commercially in the Caspian Sea in varying degrees. They are, therefore, subject to depletion through overfishing and, in addition, river dams and the fall in Caspian Sea level affect spawning migrations and spawning grounds respectively. Assessment of threatened status is complicated by lack of information on the subspecies and stocks encountered and fished in Iranian waters. Eight subspecies of *A. brashnikovi* alone are said to be found in the south Caspian Sea (Berg, 1948–49; Svetovidov, 1952), for example. Herrings also migrate seasonally for spawning and to avoid harsh winter conditions so that species and stocks encountered in the Iranian waters may be subject to overfishing or environmental degradation in Russian waters (Kazancheyev, 1976). Vodovskaya (1977) reported that catches of *A. kessleri* throughout the Caspian Sea in 1965–73 constituted 2–4% of the catch in 1938–43. Winter aggregations in the south of the Caspian had also decreased as had the already small migrations to the Azarbaijan coasts. Mamulyan (1969) stated that the spawning area of *A. kessleri volgensis* was greatly reduced by construction of the Volga dam in 1958 but a fish ladder, beginning to function in August 1961, enabled this species of herring to reproduce in the river section of the Volgograd Reservoir and progeny went down river to supplement Caspian Sea stocks. However, Vodovskaya (1977) reported that *A. kessleri volgensis*, once the main form of herring caught, is now encountered rarely so the fish ladder apparently did not alleviate the loss of spawning areas caused by the Volga dam. *A. curensis* is a poorly studied species with a more restricted distribution than other herrings in the southern part of the Caspian Sea in the region of the Kura estuary and Lenkoran coast to the south near Iranian Guilan. It may prove to be a subspecies of *A. brashnikovi.*

Family 4. Anguillidae

16. *Anguilla anguilla.* Rare.

Occasionally caught in the south Caspian Sea in Iranian waters (P. Walczak, pers. comm., 1978), and reported from Russian Azarbaijan by Abdurakhmanov & Kuliyev (1968). Its penetration into the Caspian was facilitated by the opening of the Volga-Baltic waterway and the introduction of elvers from France and England into the Volga basin. Common elsewhere in Eurasia.

Family 6. *Salmo trutta.* Endangered.

S. trutta caspius, mahi azad, of Caspian rivers has been severely depleted by overfishing, poaching with dynamite, deterioration of habitat and spawning grounds through siltation, pollution, irrigation dams, and unscreened irrigation intake canals and by the lowering of the Caspian Sea level which has made spawning migrations difficult (Walczak, 1972). The Lighvanchai brown trout is restricted to the Lighvanchai River of the Lake Reza'iyeh basin. Development of agriculture and domestication of sheep and goats have destroyed the range and watersheds. Formerly it is believed to have occupied all the streams of the Lake Reza'iyeh basin. *S. trutta macrostigma* was mentioned by Berg (1948–49) as occurring in the Karadj River. This population is considered to be *S. trutta caspius* by Saadati (1977) as is a population of trout in the Lar River. All populations of subspecies of trout are threatened in Iran by habitat destruction.

Family 7. Cyprinidae

77. *Iranocypris typhlops*. Rare.

A 'cave' fish restricted to a natural well or cave outlet of a subterranean water system at Kaaje-Ru near Bag-e-Loveh in the Zagros mountains of southwestern Iran. Since specimens near the surface may represent strays from a main subterranean population and the cave is in a remote area, this species and its habitat are unlikely to be threatened. It is, however, a rarity and only a few specimens have been caught (Bruun and Kaiser, 1950; Greenwood, 1976).

83. *Pelecus cultratus*. Rare.

A species encountered on rare occasions in the Sefid River (Berg, 1948–49) but common elsewhere in Eurasia.

22. *Abramis brama*.	Depleted.
41. *Aspius aspius*.	Depleted.
43. *Barbus brachycephalus*.	Depleted.
69. *Cyprinus carpio*.	Depleted.
86. *Rutilus frisii kutum*.	Depleted.
87. *Rutilus rutilus caspicus*.	Depleted.

These six species are found in the Caspian Sea and tributary rivers. They are commercially important species whose numbers have declined through overfishing, poaching during the spawning migration and destruction or modification of spawning habitats (Roux, 1961; Vladykov, 1964; Ralonde & Walczak, 1972; Razivi *et al.*, 1972).

A number of other cyprinid species may be classified as Indeterminate in that they are species of restricted distribution in Iran according to the literature and available field data and are thus susceptible to unfavourable environmental modifications, although they may ultimately prove to be more widespread with better field collection data, e.g. species 25, 26, 28, 49, or are species, often of restricted distribution according to the literature, which may prove to be synonyms of more widely distributed species, e.g. 32, 34, 35, 36, 38, 53, 54. So little is known about the ecological requirements of non-commercial Iranian freshwater fishes that any species in Caspian rivers may be threatened with environmental degradation and fishes like the *Schizocypris*, *Schizopygopsis* and *Schizothorax* species found in the Seistan basin may be threatened in some degree by water level fluctuations.

Family 8. Cobitidae

98. *Cobitis linea*. Rare.

Description based on a single much-damaged specimen from the Pulvar River near Persepolis in Fars Province. It has since been recollected in the type locality but it does not appear to be common.

115. *Noemacheilus smithi*. Rare.

Restricted to a 'cave' habitat with the cyprinid *Iranocypris typhlops* (q.v.) B. Sanford (pers. comm., 1979) believes that these two species should be classed as Endangered because there is some evidence of recent collapse in the 'cave' system. However, it is difficult to assess both the extent of the network of fissures and the abundance of the two species.

As in Cyprinidae a number of Cobitidae must be classified as Indeterminate until more data on the taxonomy, distribution and ecological requirements are available, e.g. species 103, 107, 111, 114, 118.

Family 9. Bagridae

121. *Mystus pelusius*. Rare.

Apparently in the Karun River but rarely collected, perhaps through inadequate field work. Common in the Tigris-Euphrates basin of Iraq.

Family 10. Siluridae

122. *Silurus glanis*. Depleted.

A commercially important species of Caspian Sea and Lake Reza'iyeh rivers whose numbers have declined through overfishing and habitat degradation (Vladykov, 1964).

Family 11. Sisoridae

123. *Glyptothorax kurdistanicus*. Rare.

One specimen reported from the Iran-Iraq border in the upper Tigris River basin at 36°N (Berg, 1949). Appears to be rare in Iran or at least poorly collected.

Family 14. Gadidae

126. *Lota lota*. Rare.

Recorded from Sefid River by Berg (1948–49) but Armantrout (1969) states that reports are uncertain. Common elsewhere in Eurasia and North America.

Family 15. Cyprinodontidae

128. *Aphanius ginaonis*. Rare.

Restricted to a hot spring at Ginao near Bandar Abbas in southern Iran (Coad, 1980). Threatened by being limited to a single habitat subject to some human interference.

129. *Aphanius mento*. Rare.

Reported from the Shatt-el-Arab on the Iran-Iraq border in Khuzistan (Al-Daham *et al.*, 1977). Appears to be rare in Iran but further collecting may reveal it to be distributed throughout Khuzistan in favourable habitats. Common elsewhere in the Middle East.

Family 21. Percidae

136. *Gymnocephalus cernua*. Rare.

Reported by Ladiges and Vogt (1965) from south Caspian Sea drainages on a map but no other records. Common elsewhere in Eurasia.

138. *Stizostedion lucioperca*. Depleted.

This species is found in Caspian Sea rivers and numbers have been depleted there by overfishing and destruction of spawning habitats. Stocks have declined drastically from the early 1930s when this species was the most abundant commercial fish species reported in the catches of the Northern Fisheries Company. Only 12% of the 1969–70 catch was mature and stocks in the southern Caspian may be on the verge of extinction (Roux, 1961; Vladykov, 1964; Griffiths *et al.*, 1972; Ralonde & Walczak, 1972).

139. *Stizostedion marinum*. Depleted.

Guseva (1975) reports that catches and stocks of this species have declined off the Turkmenian coast in the Caspian Sea where it is commercially fished.

Family 24. Gobiidae

146. *Asra turcomana*.	Rare.
151. *Benthophilus leptocephalus*.	Rare.
157. *Mesogobius nonultimus*.	Rare.
167. *Proteorhinus semipellucidus*.	Rare.

These four species are known from only one or two specimens taken in the Caspian Sea. *P. semipellucidus* may be a synonym for the more widespread species *P. marmoratus* (Berg, 1948–49). Further collecting may show these species to be widely distributed.

Family 25. Channidae

168. *Ophiocephalus gachua*. Rare.

Recorded from the Bampur River in Baluchistan (4 specimens; Nikolsky, 1899) and the Haliri River in Kerman (1 specimen; Coad, 1978). Appears to be rare, perhaps because of a lack of suitable habitats, but may be inadequate collecting. Common in Pakistan.

In addition 17. *Esox lucius* and 97. *Vimba vimba* are fished commercially in the Caspian Sea basin and may be under pressure for this reason.

ACKNOWLEDGEMENTS

This research was funded by a Pahlavi University (Shiraz, Iran) Research Council grant, number 35-A5-149-172, and by the Ichthyology Section, National Museum of Natural Sciences, Ottawa, Ontario, Canada. The author gratefully acknowledges the assistance of these institutions. I am indebted to Dr R. J. Behnke, Colorado State University, P. S. Walczak, Tarawa, Gilbert Islands and B. Sanford, Montrose, Colorado for unpublished information on Iranian fishes.

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APPENDIX 1

A check-list of Iranian freshwater fishes including brackish-water species of the Caspian Sea. Higher classification follows Nelson (1976). There are conflicting views on validity of species and their generic placement (see Coad, 1979; Saadati, 1977 for further details). Species marked with an asterisk (*) are exotic and those marked with a plus sign (+) are naturally restricted to the Caspian Sea basin within Iran.

Family 1. Petromyzonidae
1. *Caspiomyzon wagneri* +
Family 2. Acipenseridae
2. *Acipenser güldenstädti* +
3. *Acipenser nudiventris* +
4. *Acipenser persicus* +
5. *Acipenser stellatus* +
6. *Huso huso* +
Family 3. Clupeidae
7. *Alosa brashnikovi* +
8. *Alosa caspia* +
9. *Alosa curensis* +
10. *Alosa kessleri* +
11. *Alosa saposhnikovii* +
12. *Clupeonella delicatula* +
13. *Clupeonella engrauliformis* +
14. *Clupeonella grimmi* +
15. *Hilsa ilisha*
Family 4. Anguillidae
16. *Anguilla anguilla* +
Family 5. Esocidae
17. *Esox lucius* +
Family 6. Salmonidae
18. *Oncorhynchus keta**
19. *Salmo gairdneri**
20. *Salmo trutta*
21. *Coregonus lavaretus**
Family 7. Cyprinidae
22. *Abramis brama* +
23. *Abramis sapa* +
24. *Acanthalburnus microlepis* +
25. *Acanthalburnus urmianus*
26. *Acanthobrama marmid*
27. *Alburnoides bipunctatus*
28. *Alburnus atropatenae*
29. *Alburnus capito*
30. *Alburnus caudimacula*
31. *Alburnus charusini* +
32. *Alburnus doriae*
33. *Alburnus filippi*
34. *Alburnus iblis*
35. *Alburnus maculatus*
36. *Alburnus megacephalus*
37. *Alburnus orontis*
38. *Alburnus schejtan*
39. *Alburnus striatus* +
40. *Aspidoparia morar*
41. *Aspius aspius* +
42. *Aspius vorax*
43. *Barbus brachycephalus* +
44. *Barbus capito*
45. *Barbus mursa*
46. *Barbus plebejus*
47. *Barbus rajanorum*
48. *Barbus xanthopterus*
49. *Barilius mesopotamicus*
50. *Bertinius longiceps*
51. *Bertinius subquincunciatus*
52. *Blicca bjoerkna* +
53. *Capoeta barroisi*
54. *Capoeta buhsei*
55. *Capoeta capoeta*
56. *Capoeta fusca*
57. *Capoeta trutta*
58. *Carasobarbus luteus*
59. *Carassius auratus**
60. *Chalcalburnus chalcoides* +
61. *Chalcalburnus mossulensis*
62. *Chondrostoma cyri* +
63. *Chondrostoma regium*
64. *Crossochilus adiscus*
65. *Crossochilus latius*
66. *Ctenopharyngodon idella**
67. *Cyprinion macrostomus*
68. *Cyprinion watsoni*
69. *Cyprinus carpio* +
70. *Garra rossica*
71. *Garra rufa*

72. *Garra variabilis*
73. *Gobio gobio*
74. *Gobio persa*
75. *Hemigarra elegans*
76. *Hemigrammocapoeta nanus*
77. *Iranocypris typhlops*
78. *Leuciscus cephalus*
79. *Leuciscus gaderanus*
80. *Leuciscus latus*
81. *Leuciscus lepidus*
82. *Leuciscus ulanus*
83. *Pelecus cultratus* +
84. *Pimephales promelas**
85. *Rhodeus sericeus* +
86. *Rutilus frisii* +
87. *Rutilus rutilus* +
88. *Scardinius erythrophthalmus* +
89. *Schizocypris brucei*
90. *Schizopygopsis stoliczkai*
91. *Schizothorax anjac*
92. *Schizothorax pelzami*
93. *Schizothorax schumacheri*
94. *Schizothorax zarudnyi*
95. *Tinca tinca* +
96. *Tor grypus*
97. *Vimba vimba* +

Family 8. Cobitidae

98. *Cobitis linea*
99. *Cobitis taenia*
100. *Noemacheilus angorae*
101. *Noemacheilus argyrogramma*
102. *Noemacheilus baluchiorum*
103. *Noemacheilus bampurensis*
104. *Noemacheilus brandti*
105. *Noemacheilus cristatus*
106. *Noemacheilus frenatus*
107. *Noemacheilus kermanshahensis*
108. *Noemacheilus kessleri*
109. *Noemacheilus longicauda*
110. *Noemacheilus malapterurus*
111. *Noemacheilus merga* +
112. *Noemacheilus persa*
113. *Noemacheilus rhadineus*
114. *Noemacheilus sargadensis*
115. *Noemacheilus smithi*
116. *Noemacheilus stoliczkai*
117. *Noemacheilus tenuis*
118. *Noemacheilus tigris*
119. *Sabanejewia aurata*
120. *Sabanejewia caspia* +

Family 9. Bagridae

121. *Mystus pelusius*

Family 10. Siluridae

122. *Silurus glanis*

Family 11. Sisoridae

123. *Glyptothorax kurdistanicus*

Family 12. Heteropneustidae

124. *Heteropneustes fossilis*

Family 13. Ariidae

125. *Arius thalassinus*

Family 14. Gadidae

126. *Lota lota* +

Family 15. Cyprinodontidae

127. *Aphanius dispar*
128. *Aphanius ginaonis*
129. *Aphanius mento*
130. *Aphanius sophiae*

Family 16. Poeciliidae

131. *Gambusia affinis**

Family 17. Atherinidae

132. *Atherina mochon* +

Family 18. Syngnathidae

133. *Syngnathus nigrolineatus* +

Family 19. Gasterosteidae

134. *Pungitius platygaster* +

Family 20. Centrarchidae

135. *Micropterus salmoides**

Family 21. Percidae

136. *Gymnocephalus cernua* +
137. *Perca fluviatilis* +
138. *Stizostedion lucioperca* +
139. *Stizostedion marinum* +

Family 22. Cichlidae

140. Species undescribed

Family 23. Mugilidae
141. *Mugil abu*
142. *Mugil cephalus**
143. *Mugil oligolepis*
144. *Liza auratus**
145. *Liza saliens**
Family 24. Gobiidae
146. *Asra turcomana*+
147. *Benthophilus baeri*+
148. *Benthophilus ctenolepidus*+
149. *Benthophilus granulosus*+
150. *Benthophilus grimmi*+
151. *Benthophilus leptocephalus*+
152. *Benthophilus macrocephalus*+
153. *Benthophilus stellatus*+
154. *Boleophthalmus dussumieri*
155. *Hyrcanogobius bergi*+
156. *Knipowitschia longicaudata*+
157. *Mesogobius nonultimus*+
158. *Neogobius caspius*+
159. *Neogobius fluviatilus*+
160. *Neogobius gymnotrachelus*+
161. *Neogobius kessleri*+
162. *Neogobius melanostomus*+
163. *Neogobius ratan*+
164. *Periophthalmus koelreuteri*
165. *Pomatoschistus caucasicus*+
166. *Proteorhinus marmoratus*+
167. *Proteorhinus semipellucidus*+
Family 25. Channidae
168. *Ophiocephalus gachua*
Family 26. Mastacembelidae
169. *Mastacembelus mastacembelus*
Family 27. Pleuronectidae
170. *Pleuronectes flesus**