

ment and embryo abortion encountered in multi-seeded botanical fruits, in improving seed yield through PGR supplementation and in the revival of old stocks of non-viable seeds, which is a problem faced by seed banks¹⁵.

In conclusion, it has been possible to salvage abortive embryos from mature fruits which otherwise fail to express themselves in the normal course of seed propagation, by culturing them on defined medium. The watermelon genotype salvaged through this approach in the present study, proved to be an autotriploid seedless type, similar to the normal seed-derived counterparts in the same fruit.

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Long-term changes in freshwater fish species composition in North Western Ghats, Pune District

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Changes in species diversity of riverine fish fauna in North Western Ghats were deduced from five faunal checklists spread over the last six decades. Though the fish species diversity of Mula–Mutha rivers appears to be constant, loss of endemic and native species and their replacement with introduced species are worrisome. Besides heavy harvest, anthropogenic activities like dam construction, habitat destruction, biological and chemical pollution in the Mula–Mutha rivers are assumed to be responsible for the loss of over 30 native fish species during the last 60 years. Practicable conservation measures include pollution management, controlled harvesting of fish and artificial breeding of native fish species.

MONITORING the status of biota as indicators of environmental conditions, detecting threat alarms and adopting mitigating strategies, is both interesting and important¹. Such extensive studies emphasize loss of biotic diversity, which unlike other environmental threats, is irreversible². The main source of data in many such studies resides in the monitoring of changes over a time span. Monitoring serves in three ways. First, it provides evidence that change is occurring and gives insights on how drastic it is. Secondly, it predicts the driving forces for such change and lastly, it shows the need for proper conservation measures and proper management of the concerned area.

The Mula–Mutha rivers (18°31'N and 73°51'E) of North Western Ghats provide a unique opportunity to monitor the changes in the fish community, since they have been studied repeatedly during the last 65 years^{3–9} almost in the same manner, but independent of each other.

The survey conducted by Fraser in 1942, considered as the pioneering work^{3–5}, and its extension by Suter⁶ are considered together and designated as F. The work by Tonapi and Mulherkar⁷ has been designated as T, and that by Ghate and Wagh⁸ as G. The present survey has been designated as P, which is based on the work by Kharat *et al.*⁹. Three additional records, i.e. that of *Rita pavementatus*, *Nangra itchkeea* and *Crossocheilus latius* were also considered. These three fish have been considered as locally extinct from the study area of

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Table 1. Number of species recorded from each study according to categories of recent and/or past records. F indicates the study by Fraser³⁻⁵ and Suter⁶, T that by Tonapi and Mulherkar⁷, G that by Ghate and Wagh⁸ and P indicates the present study

Combination code	Combination type	Fish study				Number of species
		F	T	G	P	
1	Recorded throughout	+	+	+	+	23
2	No recent records	+	+	+	-	1
3	Only past records	+	+	-	-	4
4	Only records	+	-	-	-	11
5	No initial records	-	+	+	+	9
6		-	+	+	-	0
7	Only records	-	+	-	-	13
8	Records in last decade	-	-	+	+	10
9	Only records	-	-	+	-	3
10	Only records	-	-	-	+	4
11	Missing records	+	-	+	+	16
12	Missing records	+	+	-	+	1
13	Records after long time	+	-	-	+	4
14	Every second record	+	-	+	-	1
15	Every second record	-	+	-	+	2
	Total					102

Key: +, Present; - Absent.

Kharat *et al.*⁹; however, they have been found in the extreme upstream and downstream of the rivers. A total of 102 species were considered in this study (see Annexure). Few records from the study by Tonapi and Mulherkar⁷ have not been considered due to their doubtful presence, given their distribution in other regions far away from the study area.

Chi-square test was used to examine if species diversity differed across the four studies. Levels of similarity in species diversity between pairs of studies were judged from Jaccard similarity index, given by the formula $SJ = j/(a + b - j)$, where SJ is Jaccard similarity index, j are the common species from studies A and B, while a and b are total number of species from studies A and B respectively. Table 1 gives combinations of presence and absence of species recorded in these four studies.

A quarter of 23 species were recorded in all the four studies. This includes common species such as *Notopterus notopterus*, *Gonoproktopterus kolus*, *Danio aequipinnatus*, *Parluciosoma labiosa* and *Mystus cavasius*, whereas the rare species such as *Labeo boggut*, *Proeutropiichthys taakree taakree* and *Glyptothorax madraspatanum* are also found. *L. boggut* and *P. taakree taakree* are declining due to heavy harvesting for food and increasing load of pollution⁹.

Only one species, *Channa orientalis*, seems recently not recorded from the present study. Misidentification of *C. punctatus* as *C. orientalis* is likely possible in previous studies. We observed more than 150 individuals, but were unable to report any specimen similar to *C. orien-*

talis. This also justifies the presence of *C. punctatus* in combination code 15.

Three locally extinct species, *Labeo fimbriatus*, *Barilius barna* and *Glyptothorax lonah*, were not found in the surveys during the last ten years. The probable driving forces are heavy harvesting and introduction of exotic fish⁹. Another fish, *Salmostoma phulo*, has not been recorded, probably due to its misidentification. Talwar and Jhingran¹⁰ have argued that *S. novacula* but not *S. phulo* is present in the Western Ghats. This is also the reason for the presence of *S. novacula* in combination code 8, i.e. its presence in surveys during the last ten years.

Only records by F comprise fish such as *Anguilla bengalensis*, *Tor khudree*, *Schismatorhynchus nukta*, *Barilius gatensis*, *Mystus gulio* and *Bagarius bagarius*, which are suspected to have become locally extinct due to heavy harvesting^{9,11}. Another reason for the extinction of large fish like *A. bengalensis*, *T. khudree* and *B. bagarius* is habitat loss due to siltation. Hora and Mishra⁴ report *Labeo potail* as a synonym of *L. porcellus*. However, later studies define this species as *L. porcellus*. Identification crisis between *Nemacheilus denisoni denisoni* and *N. denisoni dayi*, due to insignificant difference¹², accounts for the report of *N. denisoni dayi* only by Fraser. This also explains the presence of *N. denisoni denisoni* in combination code 5. Other species such as *Salmostoma clupeoides* and *Glyptothorax conirostre poonaensis* are extinct⁹, but the reasons are yet unknown.

No initial records show presence of introduced species such as *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala mrigala*. These species were introduced for their eco-

nomical importance in food value. Other species like *Rohtee ogilbii*, *Myxus malabaricus* and *Chanda nama*, though common, were not recorded by Fraser.

Thirteen species were reported only by Tonapi and Mulherkar⁷. Many of these species are not distributed in this region. Species like *Notopterus chitala*, *Osteochilus thomassi* and *Rita rita* might have been introduced for their food value, but they have not been reported since the last ten years^{8,9}. Presence of species such as *Channa striatus* and *Nemacheilus striatus* is doubtful⁹.

Records in the last decade comprise introduced species such as *Cyprinus carpio*, *Labeo ariza*, *Gambusia affinis*, *Poecilia reticulata*, *Heteropneustes fossilis*, *Oreochromis mossambica* and *Rhinomugil corsula*, of which *C. carpio*, *H. fossilis* and *O. mossambica* were introduced for their food value, whereas *G. affinis* and *P. reticulata* were introduced to control malaria. Gangetic fish, *R. corsula*, is spreading fast all over peninsular India¹³, probably due to accidental introduction along with the seeds of cultivated carps¹⁴.

Only records by G have a single specimen of *Macropodus cupanus* from Mutha river¹⁵, which is distributed chiefly in South India. The reasons for the presence of *Danio devario* and *Salmostoma acinaces* are still unknown.

Only records by P comprise four species, viz. *Cirrhinus cirrhosus*, *Danio malabaricus*, *Parlusiosoma labiosa* and *Xiphophorus hellerii*. *C. cirrhosus* is commonly found throughout the Deccan¹⁶, while the taxonomic status of *D. malabaricus* is still uncertain due to its greater resemblance with *D. aequipinnatus*¹⁷. *X. hellerii* was introduced as an aquarium fish, while reasons for the presence of *P. labiosa* are not known.

Missing records by T comprise common species such as *Cirrhinus reba*, *Labeo calbasu*, *Osteobrama neilli* and *Nemacheilus anguilla* (reasons unknown).

Missing records by G account for the rare species, *Rita pavementatus*, which might have been missed due to seasonality.

Records after a long time account for the four species, among which *Nemacheilus evezardi* and *Garra gotyla gotyla* are common fish found throughout the stretch of Mula and Mutha rivers⁹. Stabilization of pollution levels in recent years and misidentification are the probable reasons for the report of *N. evezardi*. Reasons for discontinuous records of *G. gotyla gotyla* are unknown. *Puntius sarana sarana* and *Ompok pabo* are rarely found and their population is declining due to heavy harvesting and pollution⁹.

Every second record by F and G comprises a single species, *Parapsilorhynchus tentaculatus*, only found in primary streams of Mutha river, and its absence in the present study might have been due to its less abundance.

Every second record by T and P includes two species, *Puntius conchoni* and *Channa punctatus*, among which *P. conchoni* is occasionally found in these rivers⁹.

Table 2. Species diversity level across four studies. Key as given in Table 1

Type	F	T	G	P	Chi-square
Total	61	53	63	69	2.131
Unique	11	13	3	4	2.198
Shared by > 1	51	44	61	65	4.932

No significant difference in species diversity across four studies ($P > 0.1$).

Table 3. Number of common species in various studies. Key as given in Table 1

Study	Common species out of 102
F-T	29
F-G	41
F-P	44
T-G	33
T-P	35
G-P	58
Chi-square	13.4

There is significant difference in number of common species ($P < 0.05$).

Table 4. Similarity among the four studies. Key as given in Table 1

	F	T	G	P
F	1	0.341	0.494	0.512
T		1	0.398	0.402
G			1	0.784
P				1

Table 2 shows that there is no significant difference either in the number of total species or unique species, or the species shared by more than one study among the four studies. However, there is significant difference in the species shared by any two studies (Table 3). Though there is no significant change in the total number of species, the species composition has been drastically altered from native species to introduced species over the years. Endemic fish like *Glyptothorax conirostre poonaensis*, with Mula-Mutha rivers as the type locality, have become extinct. Introduction of exotic species like *C. catla*, *O. mossambica*, etc. has affected the existence of native fish like *B. bagarius*, *L. fimbriatus*, due to competition as well as predation.

Besides exotic species, construction of dams, pollution of water and overfishing are other detrimental factors affecting the native fish population. There are four large dams across the Mula and Mutha rivers. The prevention of upstream and downstream fish movement by dams is one of the most negative impacts on the migratory species¹¹. Species such as *A. bengalensis* might have been affected due to loss of its migratory path.

Annexure. Combined checklist of fish in Pune.

Family/species ^a	<i>N. moreh</i> (Sykes)
	<i>N. rueppelli</i> (Sykes)
Notopteridae	<i>N. striatus</i> Day
<i>Notopterus chitala</i> (Hamilton – Buchanan)	Cobitidae
<i>N. notopterus</i> (Pallas)	<i>Lepidocephalus guntea</i> (Hamilton – Buchanan)
Anguillidae	<i>L. thermalis</i> (Valenciennes)
<i>Anguilla bengalensis bengalensis</i> (Grey)	Bagridae
Cyprinidae	<i>Aorichthys seenghala</i> (Sykes)
<i>Catla catla</i> (Hamilton – Buchanan)	<i>Mystus bleekeri</i> (Day)
<i>Cirrhinus cirrhosus</i> (Bloch)	<i>M. cavasius</i> (Hamilton – Buchanan)
<i>C. fulungee</i> (Sykes)	<i>M. gulio</i> (Hamilton – Buchanan)
<i>C. mrigala mrigala</i> (Hamilton – Buchanan)	<i>M. malabaricus</i> (Jerdon)
<i>C. reba</i> (Hamilton – Buchanan)	<i>Rita kuturnee</i> (Sykes)
<i>Cyprinus carpio communis</i> Linnaeus	<i>R. pavimentatus</i> (Valenciennes)
<i>Gonoproktopterus kolus</i> (Sykes)	<i>R. rita</i> (Hamilton – Buchanan)
<i>G. thomassi</i> (Day)	Siluridae
<i>Labeo ariza</i> (Hamilton – Buchanan)	<i>Ompok bimaculatus</i> (Bloch)
<i>L. boggut</i> (Sykes)	<i>O. pabo</i> (Hamilton – Buchanan)
<i>L. calbasu</i> (Hamilton – Buchanan)	<i>Wallago attu</i> (Schneider)
<i>L. fimbriatus</i> (Bloch)	Schilbeidae
<i>L. kawrus</i> (Sykes)	<i>Proeutropiichthys taakree taakree</i> (Sykes)
<i>L. porcellus</i> (Heckel)	<i>Silonia childreni</i> (Sykes)
<i>L. potail</i> (Sykes)	Sisoridae
<i>L. rohita</i> (Hamilton – Buchanan)	<i>Bagarius bagarius</i> (Hamilton – Buchanan)
<i>L. sindensis</i> (Day)	<i>Glyptotharax conirostre poonaensis</i> Hora
<i>Osteobrama cotio peninsularis</i> Silas	<i>G. lonah</i> (Sykes)
<i>O. neilli</i> (Day)	<i>G. madraspatanum</i> (Day)
<i>O. vigorsii</i> (Sykes)	<i>Nangra itchkeea</i> (Sykes)
<i>Osteochilus (Osteochilichthys) nashii</i> (Day)	Heteropneustidae
<i>O. (O.) thomassi</i> (Day)	<i>Heteropneustus fossilis</i> (Bloch)
<i>Puntius amphibius</i> (Valenciennes)	Belonidae
<i>P. arenatus</i> (Day)	<i>Xenentodon cancila</i> (Hamilton – Buchanan)
<i>P. chola</i> (Hamilton – Buchanan)	Aplocheilidae
<i>P. conchoniis</i> (Hamilton – Buchanan)	<i>Aplocheilus lineatus</i> (Valenciennes)
<i>P. jerdoni</i> (Day)	<i>A. panchax</i> (Hamilton – Buchanan)
<i>P. melanostigma</i> (Day)	Poeciliidae
<i>P. sarana sarana</i> (Hamilton – Buchanan)	<i>Gambusia affinis</i> (Baird & Girard)
<i>P. sarana subnasutus</i> (Valenciennes)	<i>Poecilia (Lebestic) reticulata</i> Peters
<i>P. sophore</i> (Hamilton – Buchanan)	<i>Xiphophorus hellerii</i> (Heckel)
<i>P. ticto ticto</i> (Hamilton – Buchanan)	Ambassidae
<i>Rohitee ogilbii</i> Sykes	<i>Chanda nama</i> Hamilton – Buchanan
<i>Schismatorhynchus (Nukta) nukta</i> (Sykes)	<i>Pseudambassis ranga</i> (Hamilton – Buchanan)
<i>Tor khudree</i> (Sykes)	Cichlidae
<i>Chela laubuca</i> (Hamilton – Buchanan)	<i>Oreochromis mossambica</i> (Peters)
<i>Salmostoma acinaces</i> (Valenciennes)	Mugilidae
<i>S. boopis</i> (Day)	<i>Rhinomugil corsula</i> (Hamilton – Buchanan)
<i>S. clupeoides</i> (Bloch)	Gobiidae
<i>S. novacula</i> (Valenciennes)	<i>Glossogobius giuris</i> (Hamilton – Buchanan)
<i>S. phulo</i> (Hamilton – Buchanan)	Belontiidae
<i>Amblypharyngodon mola</i> (Hamilton – Buchanan)	<i>Macropodus cupanus</i> (Valenciennes)
<i>Barilius barna</i> (Hamilton – Buchanan)	Channidae
<i>B. bendelisis</i> (Hamilton – Buchanan)	<i>Channa marulius</i> (Hamilton – Buchanan)
<i>B. gatensis</i> (Valenciennes)	<i>C. orientalis</i> Bloch & Schneider
<i>Danio aequipinnatus</i> (McClelland)	<i>C. punctatus</i> (Bloch)
<i>D. devario</i> (Hamilton – Buchanan)	<i>C. striatus</i> (Bloch)
<i>D. malabaricus</i> (Jerdon)	Mastacembelidae
<i>Parluciosoma daniconius</i> (Hamilton – Buchanan)	<i>Mastacembelus armatus</i> (Lacepede)
<i>P. labiosa</i> (Mukerji)	
<i>Crossocheilus latius latius</i> (Hamilton – Buchanan)	
<i>Garra gotyla gotyla</i> (Gray)	
<i>G. mullya</i> (Sykes)	
Parapsilorhynchidae	
<i>Parapsilorhynchus tentaculatus</i> (Anandale)	
Balitoridae	
<i>Nemacheilus anguilla</i> Anandale	
<i>N. denisoni dayi</i> Hora	
<i>N. denisoni denisoni</i> Day	
<i>N. evezardi</i> Day	

^aTaxonomic status adapted from Talwar and Jhingran¹⁰.

In the polluted stretch of these rivers, tolerant species such as *O. mossambica*, *P. reticulata* and *G. affinis* as well as the air-breathing fish such as *H. fossilis* are thriving well and the sensitive native species such as *C. latius latius*, *O. pabo* and *P. taakree taakree* are assumed to be threatened by increasing water pollution. Over-fishing has wiped out fish such as *L. fimbriatus*, *S. nukta*, *T. khudree*, *S. childreni*, *B. bagarius* and *G. lonah*⁹, whereas *L. boggut*, *L. ariza* and *Wallago attu* have been driven to the verge of extinction.

Table 4 shows that the survey by Tonapi and Mulherkar⁷ has least similarity with any other survey. One prediction could be that the different species recorded by Tonapi and Mulherkar, introduced during the period of their study, might not have survived in the later years. Since there was a large gap from 1963 to 1992, this predication cannot be justified.

Although the fish species diversity levels in the Mula-Mutha rivers appear to be constant (Table 2), it is at the cost of endemic and native species replaced with exotic species. On the major background of catastrophic loss of biodiversity^{2,18}, setting conservation priorities is necessary². Various strategies applied for conservation of fish include halting of siltation, promoting controlled harvest, exploring checks on growth of exotic species, controlling on the water pollution and construction of fish ladders on dams.

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