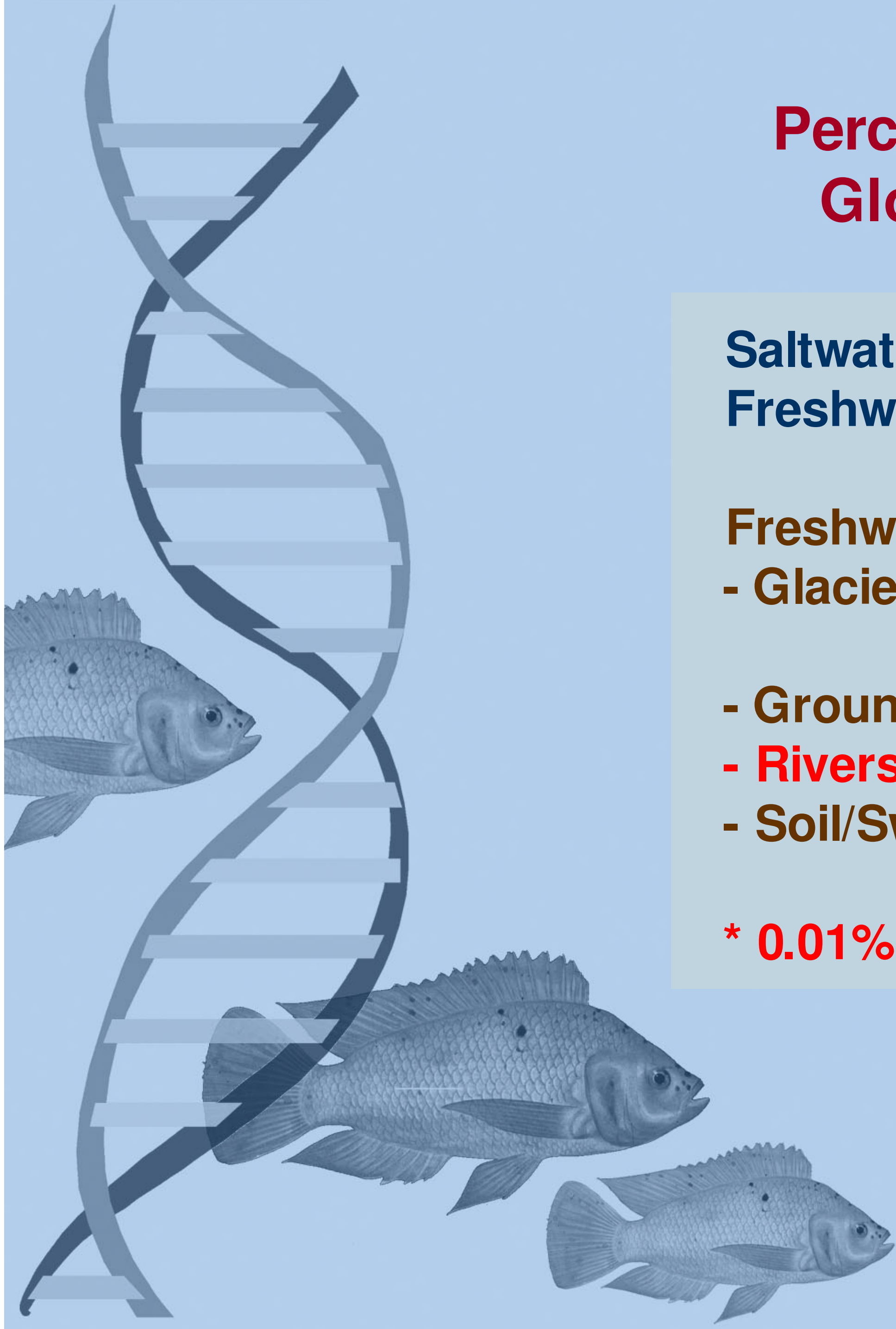
Climate Change and Freshwater Fish Genetic Resources

by Roger Pullin

Presentation to the Workshop on Climate Change and Biodiversity for Food and Agriculture, 13-14 February, 2008, FAO, Rome, Italy



Percentage Composition of Global Water Resources

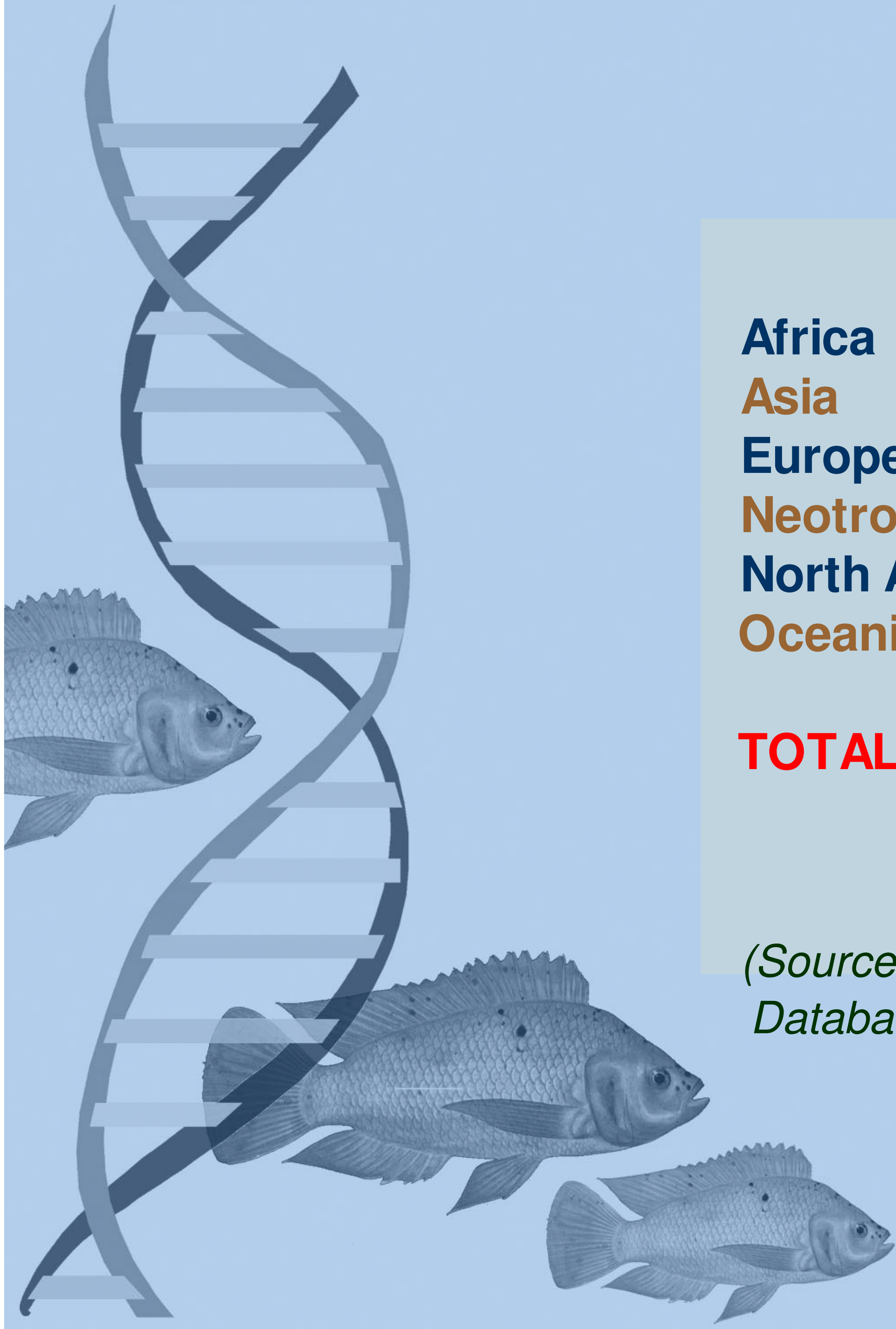
Saltwaters	97.5%
Freshwater	2.5%

Freshwaters (by %)

- Glaciers/Permanent snow cover	69.0%
- Groundwater	30.0%
- Rivers and Lakes	0.3%*
- Soil/Swamp/Permafrost	0.9%

* 0.01% of Global Waters !

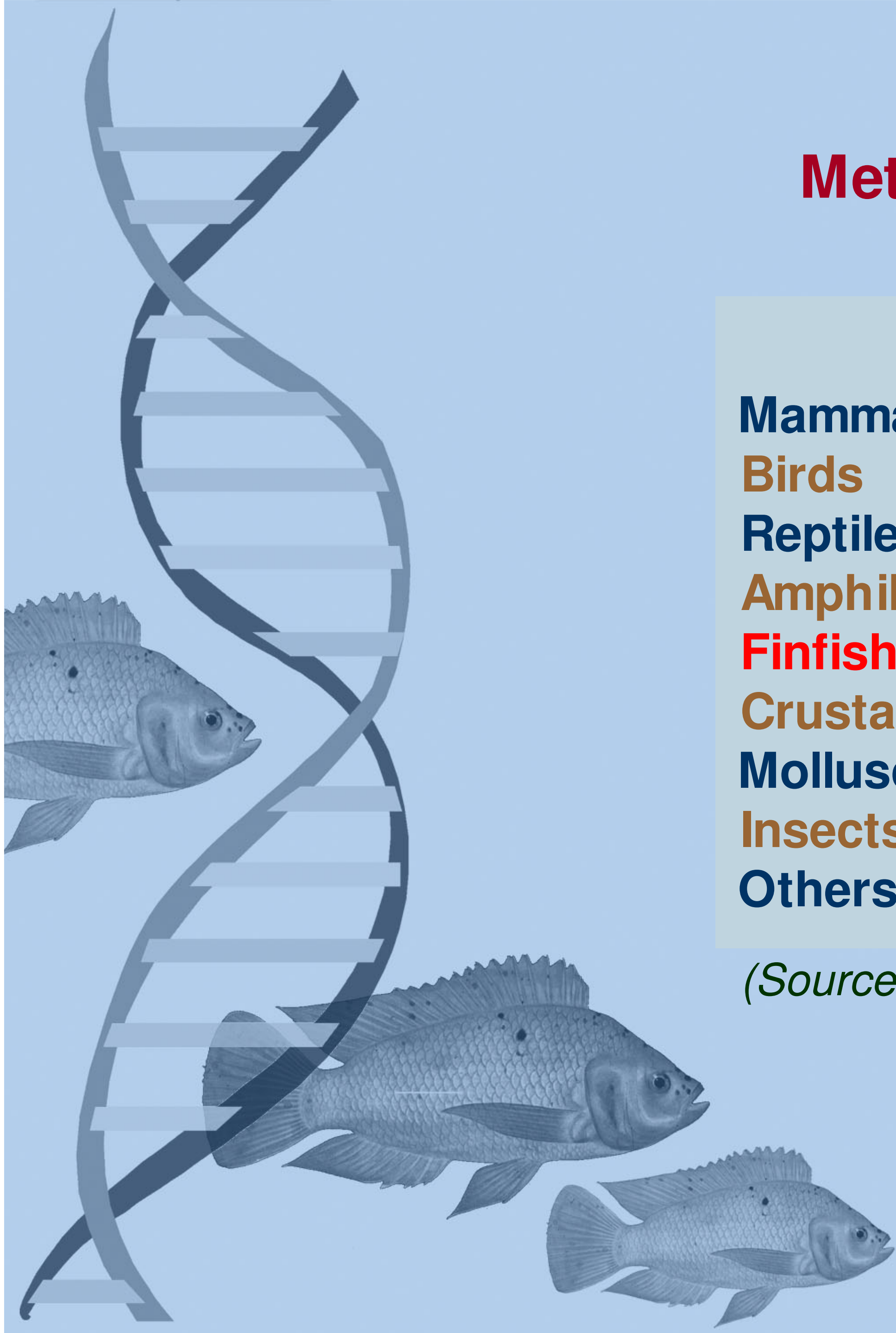
(Stiassny 1996)



Inland (non-marine) Wetland Areas*

	Million Hectares
Africa	131
Asia	286
Europe	26
Neotropics	159
North America	287
Oceania	28
TOTAL	**917**

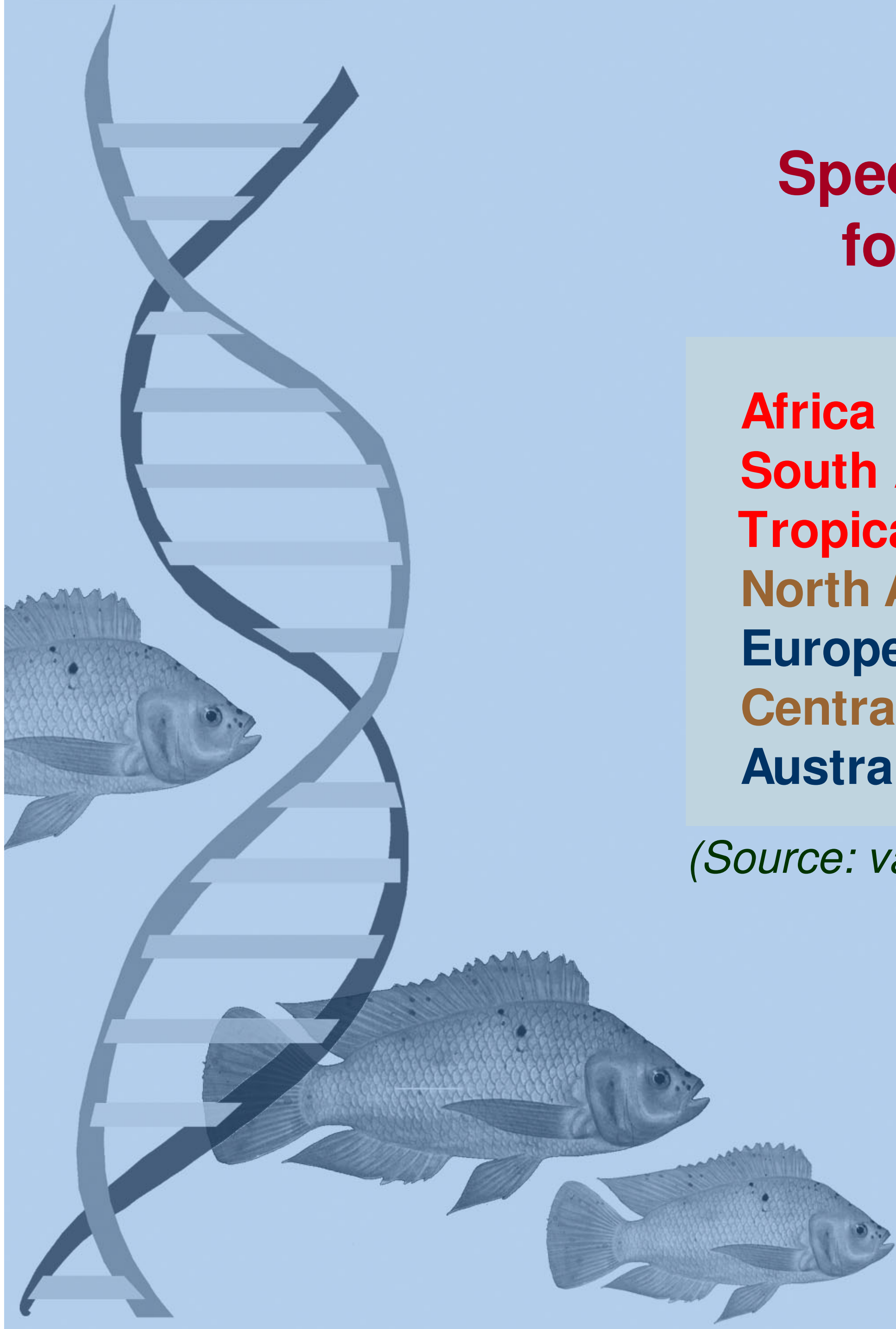
(Source: 2004 Global Lakes and Wetlands Database; various authors; cited by MEA 2005c)



Metazoan Animal Diversity in Freshwaters

	No. of species
Mammals	c.122
Birds	c.1,800
Reptiles	c.250
Amphibians	3,533
Finfish	13,400
Crustaceans	c.12,000
Molluscs	c.6,000
Insects	>50,000
Others	c.15,000

(Source: summarized from MEA 2005c)



Species Diversity by Region for Freshwater Teleosts

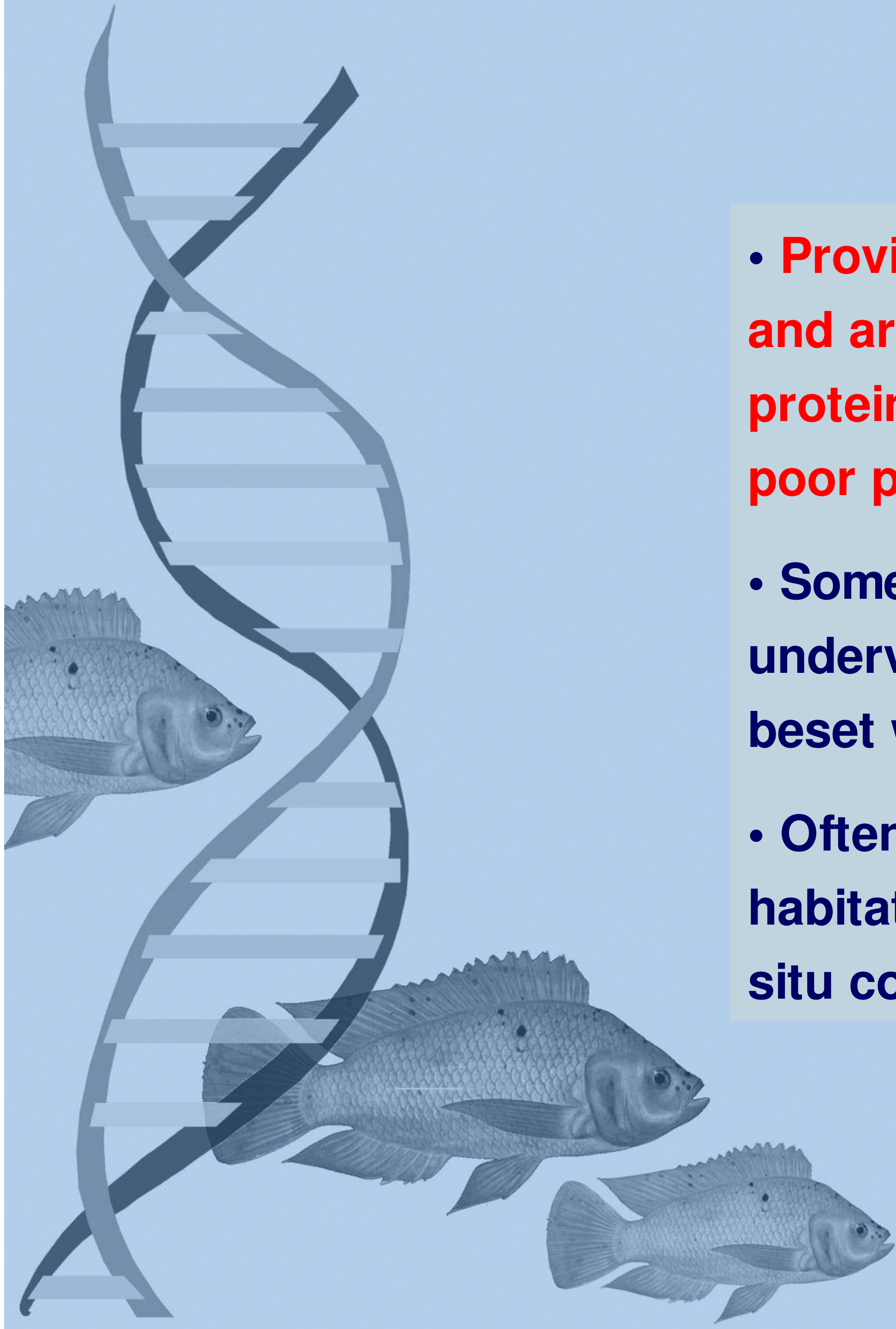
Africa	2,780 +
South America	2,400 – 4,000
Tropical Asia	2,500 ++
North America	1,033
Europe & former USSR	319
Central America	242
Australia	188

(Source: various authors cited by Stiassny, 1996)

Freshwater Ecosystem Goods and Services

- **PROVISIONING - food, water, fiber etc., gene pools**
- **REGULATORY - carbon sinks, waste management etc.**
- **CULTURAL - spiritual, recreational, educational etc.**
- **SUPPORTING - soil formation, nutrient cycling etc.**

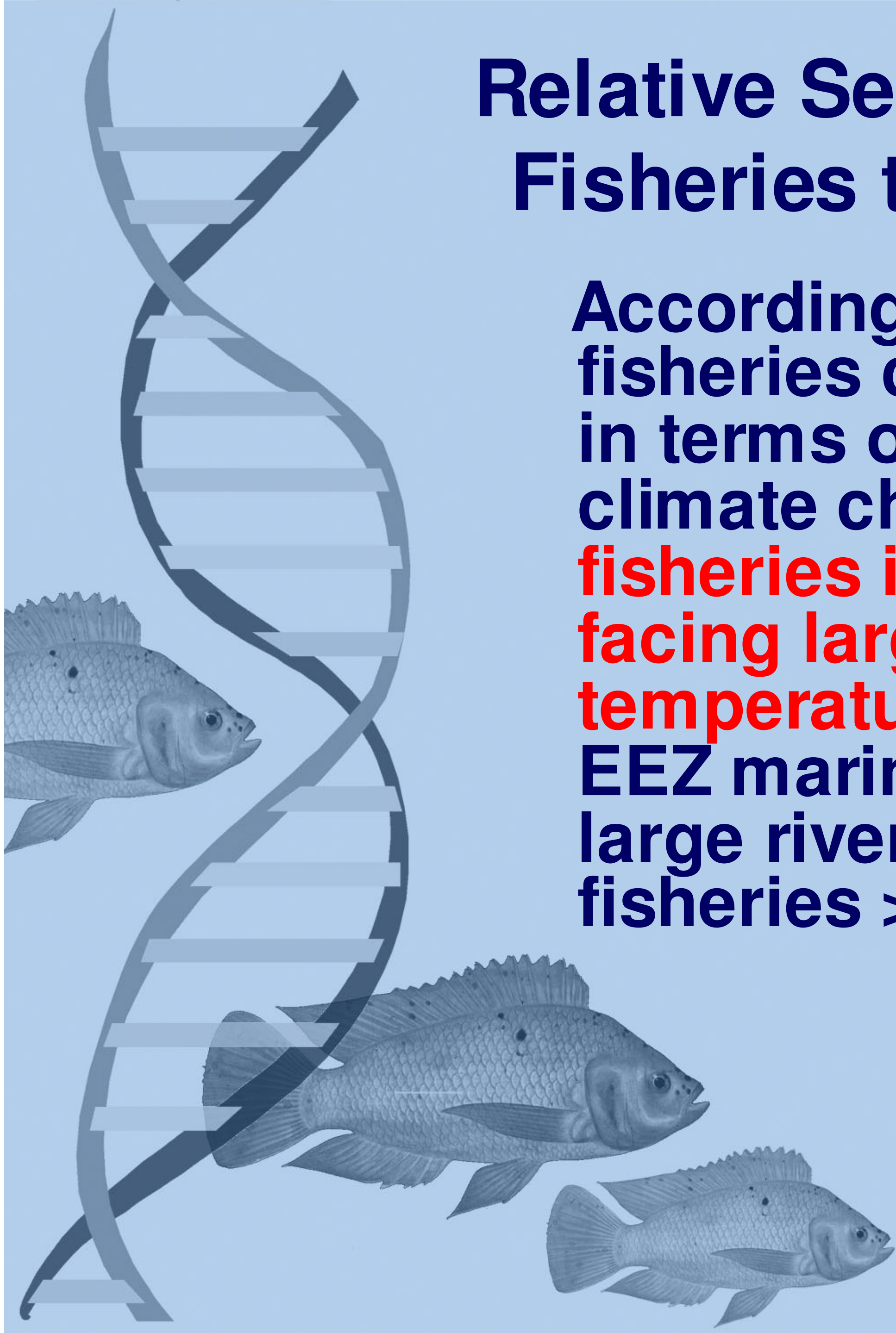
(MEA 2005c)



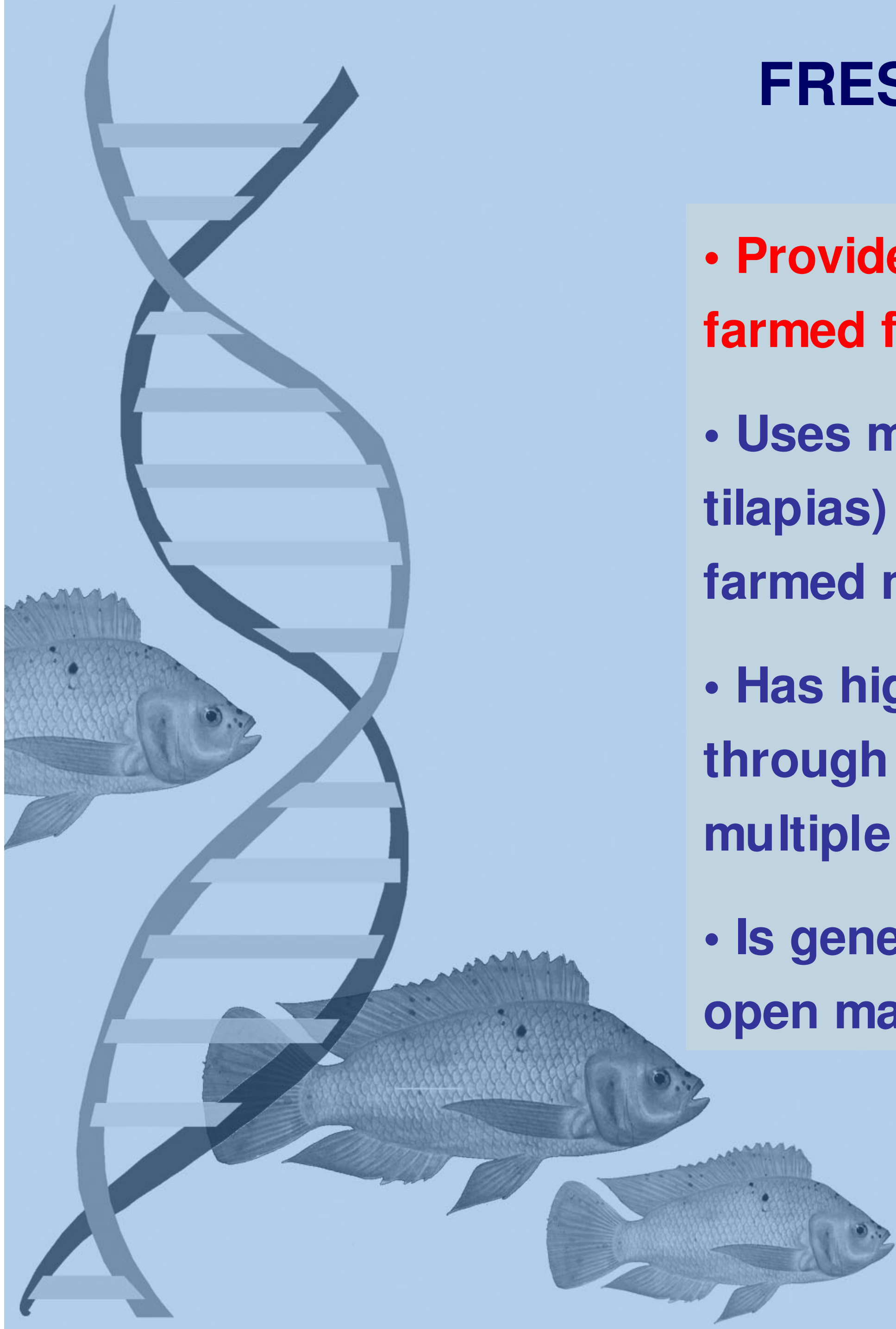
Inland Capture Fisheries

- Provide about 10% of world finfish supply and are the main or sole source of animal protein, micronutrients and vital lipids for poor people in some developing countries
- Some have scope for growth; most are undervalued, mismanaged, vulnerable and beset with inaccurate statistics
- Often involve target populations and habitats that are of high importance for in situ conservation of FiGR for aquaculture

Relative Sensitivity of Capture Fisheries to Climate Change

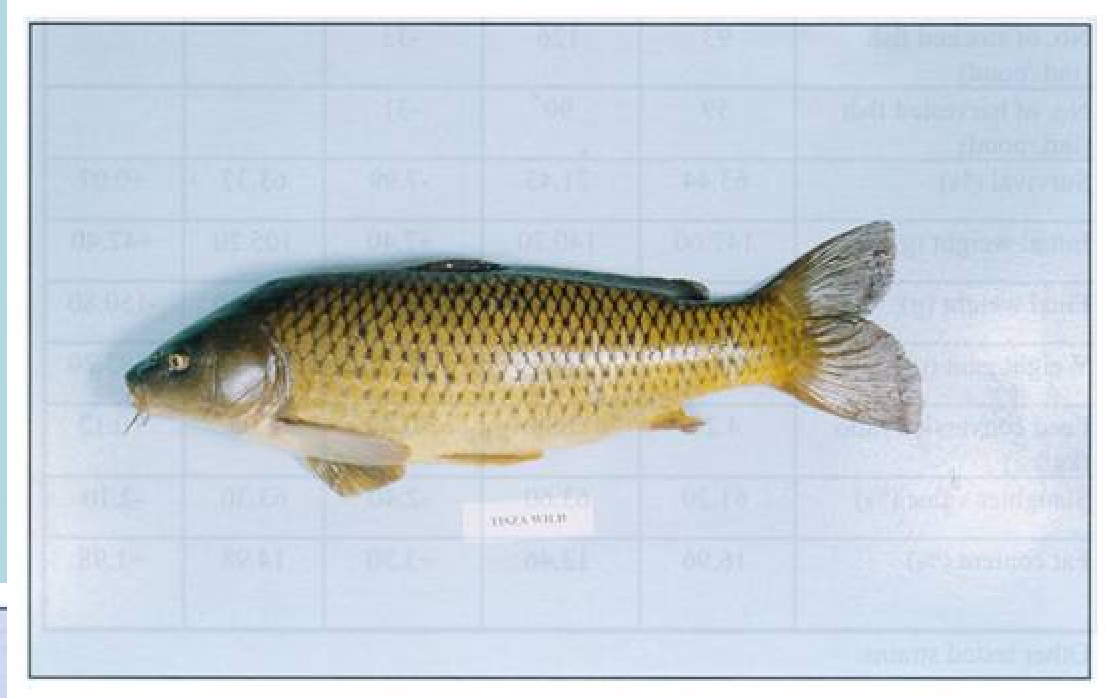


According to Sharp (2003), capture fisheries can be ranked as follows in terms of their sensitivities to climate change: freshwater fisheries in small rivers and lakes, facing large changes in temperature and precipitation > EEZ marine fisheries > fisheries in large rivers and lakes > estuarine fisheries > and high seas fisheries.

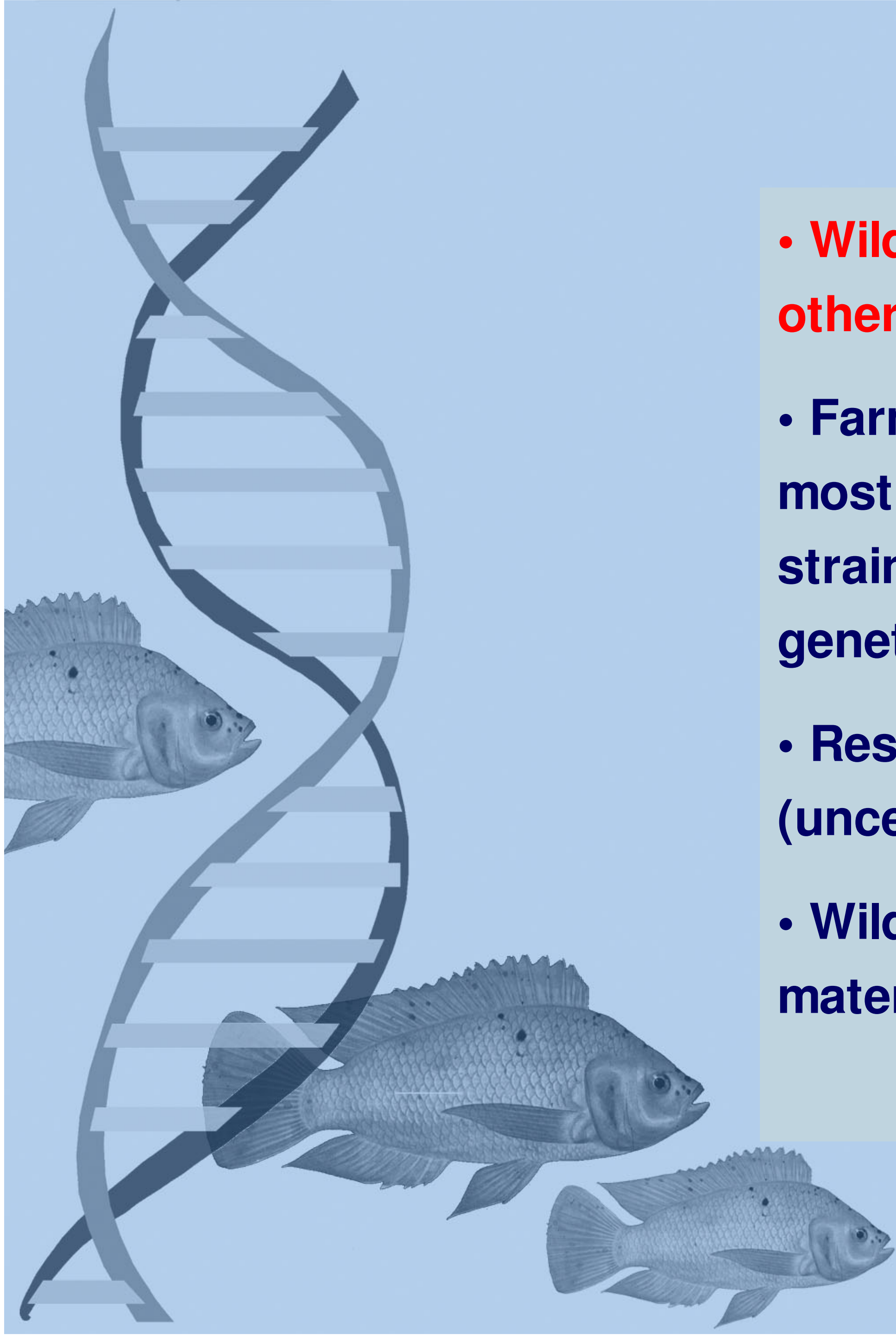


FRESHWATER AQUACULTURE

- Provides over 80% of world production of farmed finfish
- Uses mostly species (e.g., carps and tilapias) that have lower trophic levels than farmed marine finfish
- Has high scope for growth, especially through integration with other sectors and multiple use of water
- Is generally less risky than farming in open marine environments

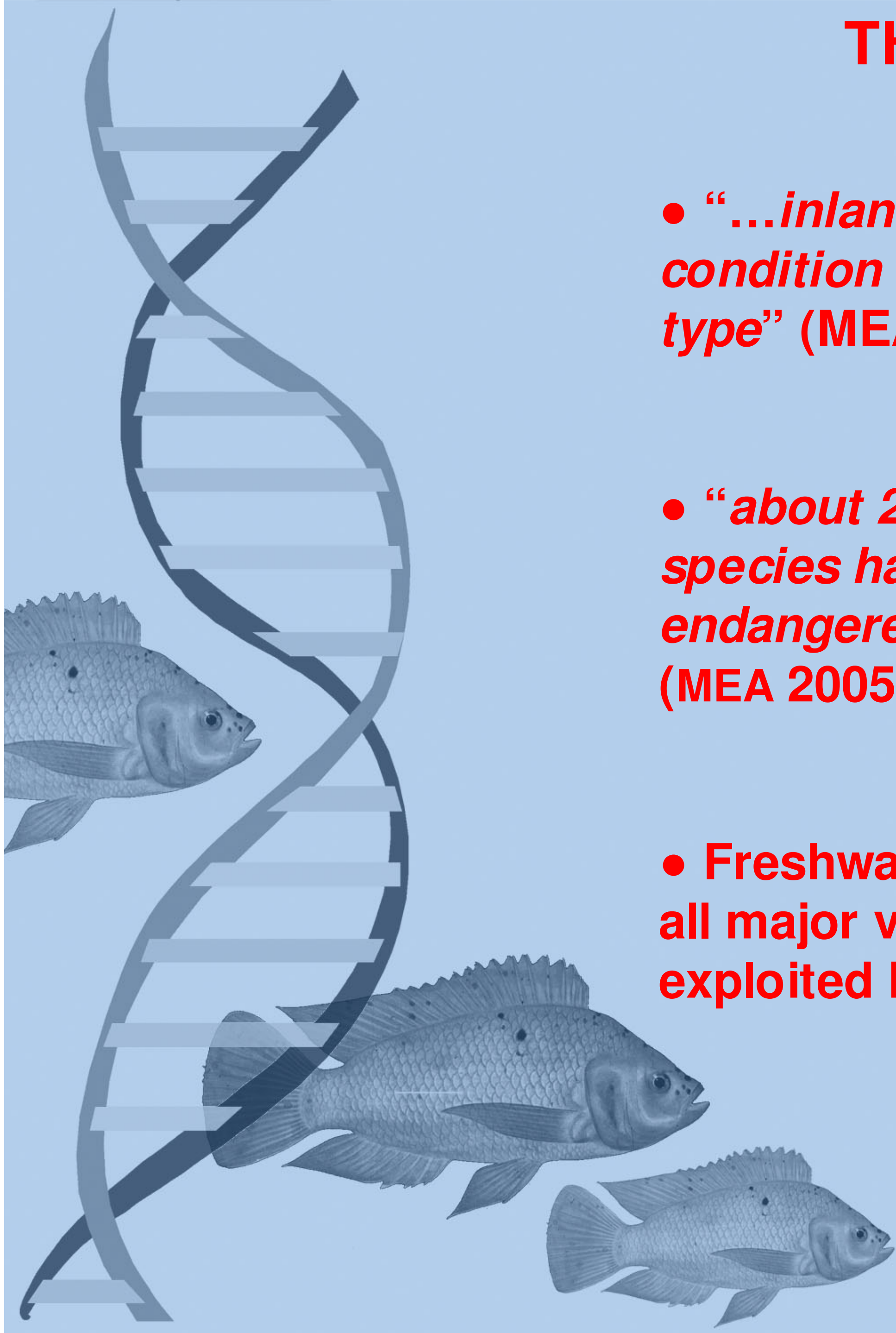


Tinza wild and Szarvas hybrid carp from Hungrary



THREATENED FiGR

- Wild types!! (in open freshwaters and other wetlands)
- Farmed types, other than the latest and most profitable available (selectively bred strains, hybrids, polyploids, other genetically altered forms)
- Research material in laboratories etc., (uncertain funding)
- Wild types, farmed types and research material in genebanks (uncertain funding)



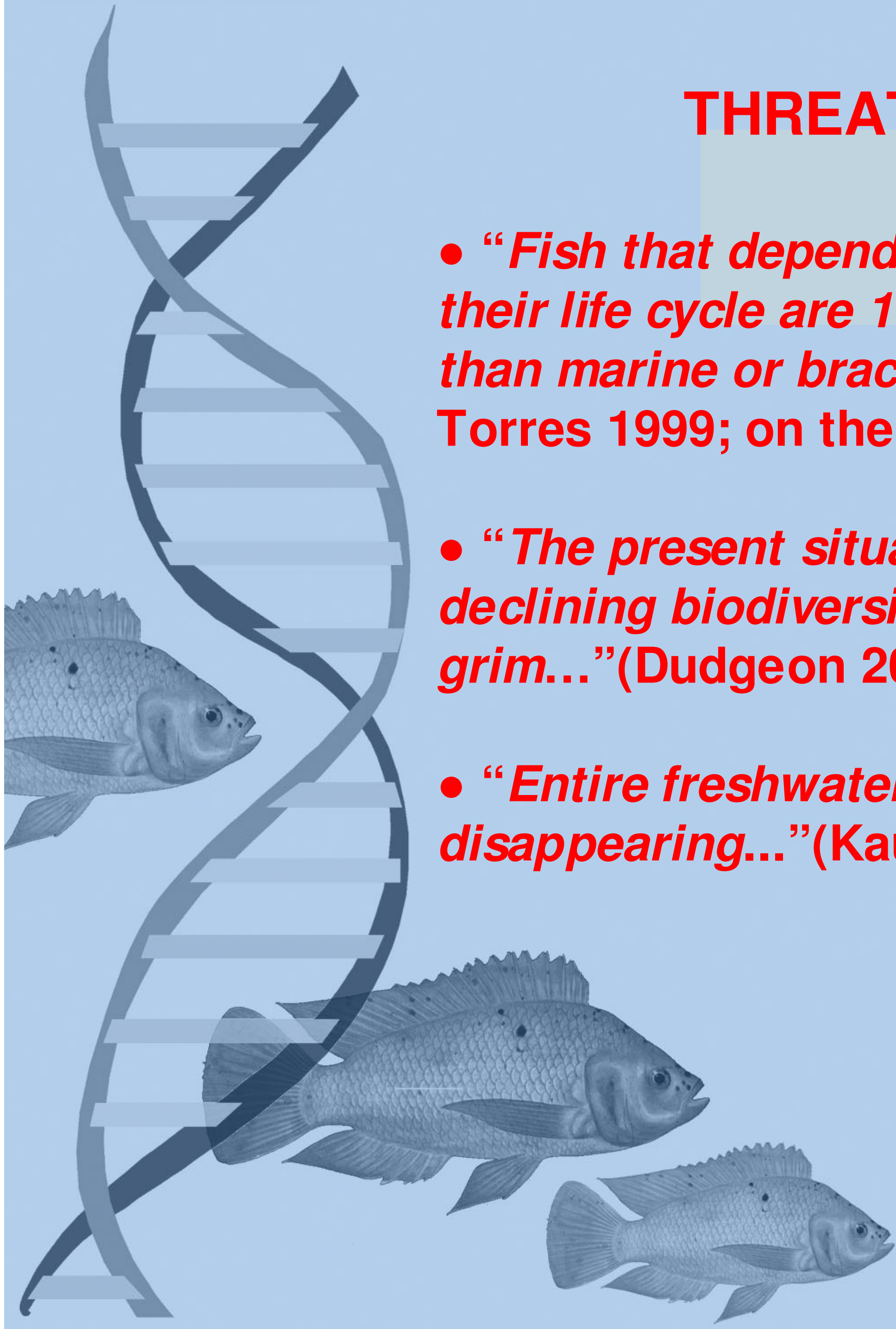
THREATENED WILD FiGR

- “…*inland water ecosystems are in worse condition than any other broad ecosystem type*” (MEA 2005a)

- “*about 20% of the world’s…freshwater fish species have been listed as threatened, endangered or extinct in the last few decades*” (MEA 2005b)

- Freshwater fishes are the most threatened of all major vertebrate species groups that are exploited by humans (Bruton 1995)

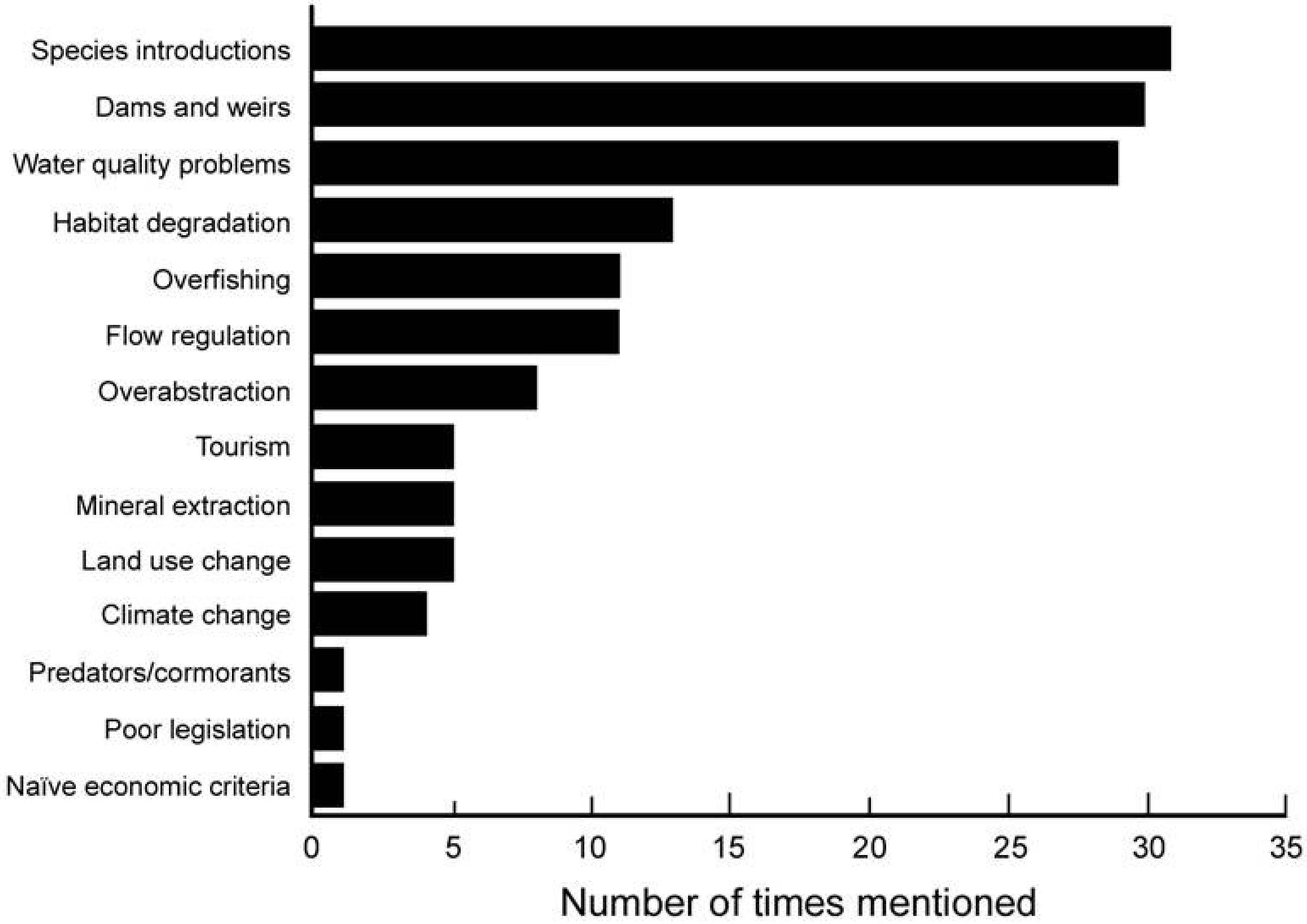
THREATENED WILD FiGR



- "*Fish that depend upon freshwater at any stage of their life cycle are 10 times more likely to be threatened than marine or brackishwater fishes*" (Froese and Torres 1999; on the IUCN Red LIST)

- "*The present situation is one of species loss in declining biodiversity. The prognosis is grim…*"(Dudgeon 2000; on Asian tropical rivers)

- "*Entire freshwater fish faunas are disappearing…*"(Kaufman 1992; on Lake Victoria)

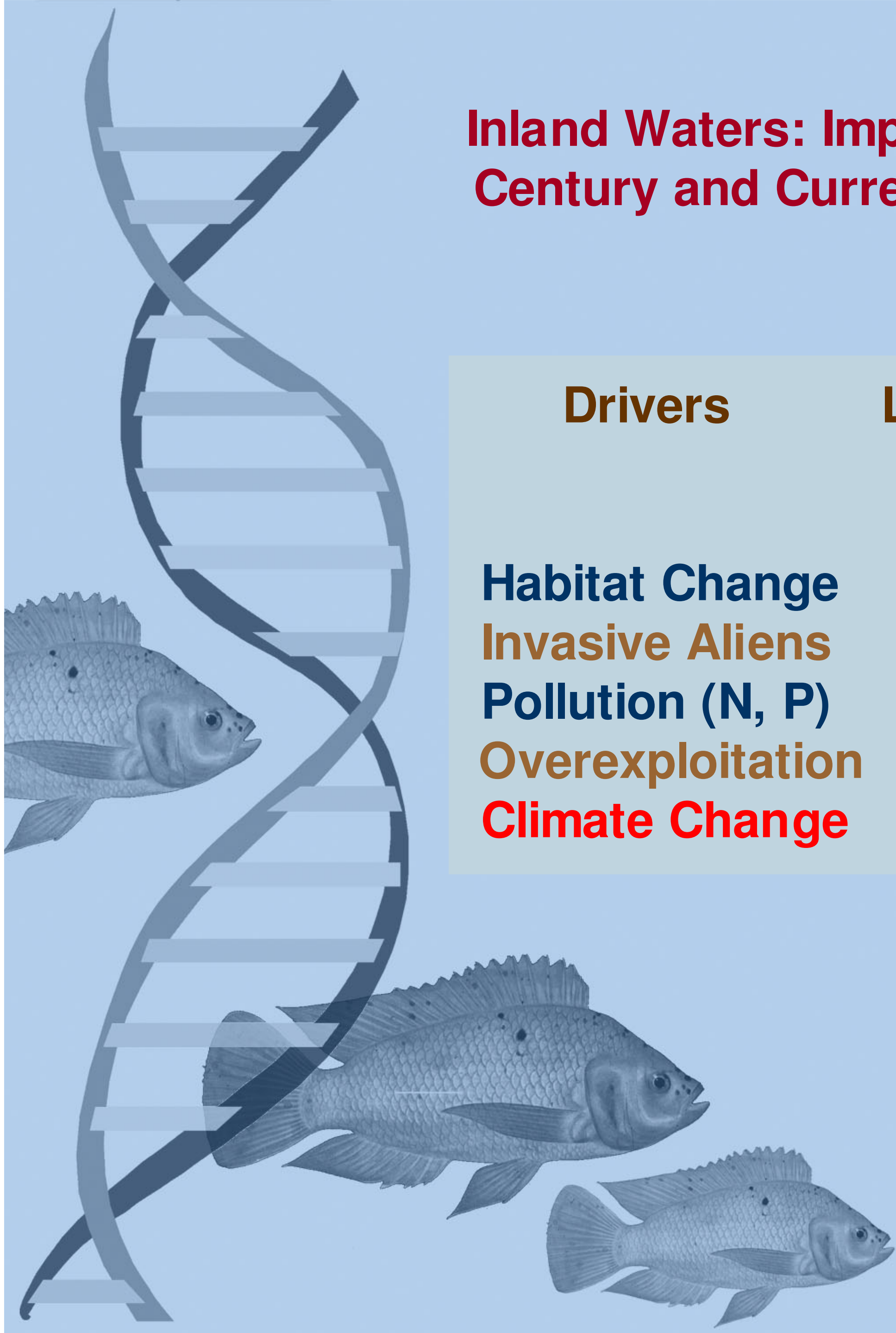


Principal threats to freshwater fishes based on assessment of the literature (Cowx, 2002).

Climate Change : Freshwater Ecosystems

"*It is arguable whether or not climate change has already affected inland waters and their species, but it is anticipated (*medium certainty*) that it will directly or indirectly affect the biota and services provided by inland waters*" (MEA 2005c)

"*The effects of climate change on wetland taxa are generally considered to be additive to the impacts of direct drivers such as habitat degradation*" (MEA 2005b)



Inland Waters: Impacts on Biodiversity Over the Last Century and Current Trends for Climate Change and Other Drivers

Drivers	Last Century Impacts	Current Trends for Impacts
Habitat Change	Very high	Very rapid increase
Invasive Aliens	High	Very rapid increase
Pollution (N, P)	Very high	Very rapid increase
Overexploitation	Moderate	Continuing
Climate Change	Low	Very rapid increase

(Source: MEA 2005b)

Threats to Open Water Tilapia Populations

"…the current drought could be threatening the critical refugium populations of Oreochromis esculentus *and* Oreochromis variabilis *in the Lake Kyoga Basin north of Lake Victoria…………Many are assuming that* O. esculentus *is secure because of the introduced population in Nyumba ya Mungo reservoir, but there is substantial genetic differentiation among the various relict and introduced populations that should not be squandered"*

(Kaufman 2006: tilapia@lists.unh.edu).

Main and sole natural distributions of Nile tilapia subspecies

Oreochromis niloticus niloticus (Yarkon River, Lower Nile, Jebel Marra, Lake Chad Basin, Niger, Benue, Volta, Gambia and Sénégal Rivers)

O.n. eduardianus (Lakes Albert, George, Kivu and Tanganyika)

O.n. vulcani (Lake Turkana)

O.n. baringoensis (Lake Baringo)

O.n. tana (Lake Tana)

O.n. cancellatus (Awash River)

O.n sugutae (Suguta River)

O.n.filoa (Hot springs! – Awash)

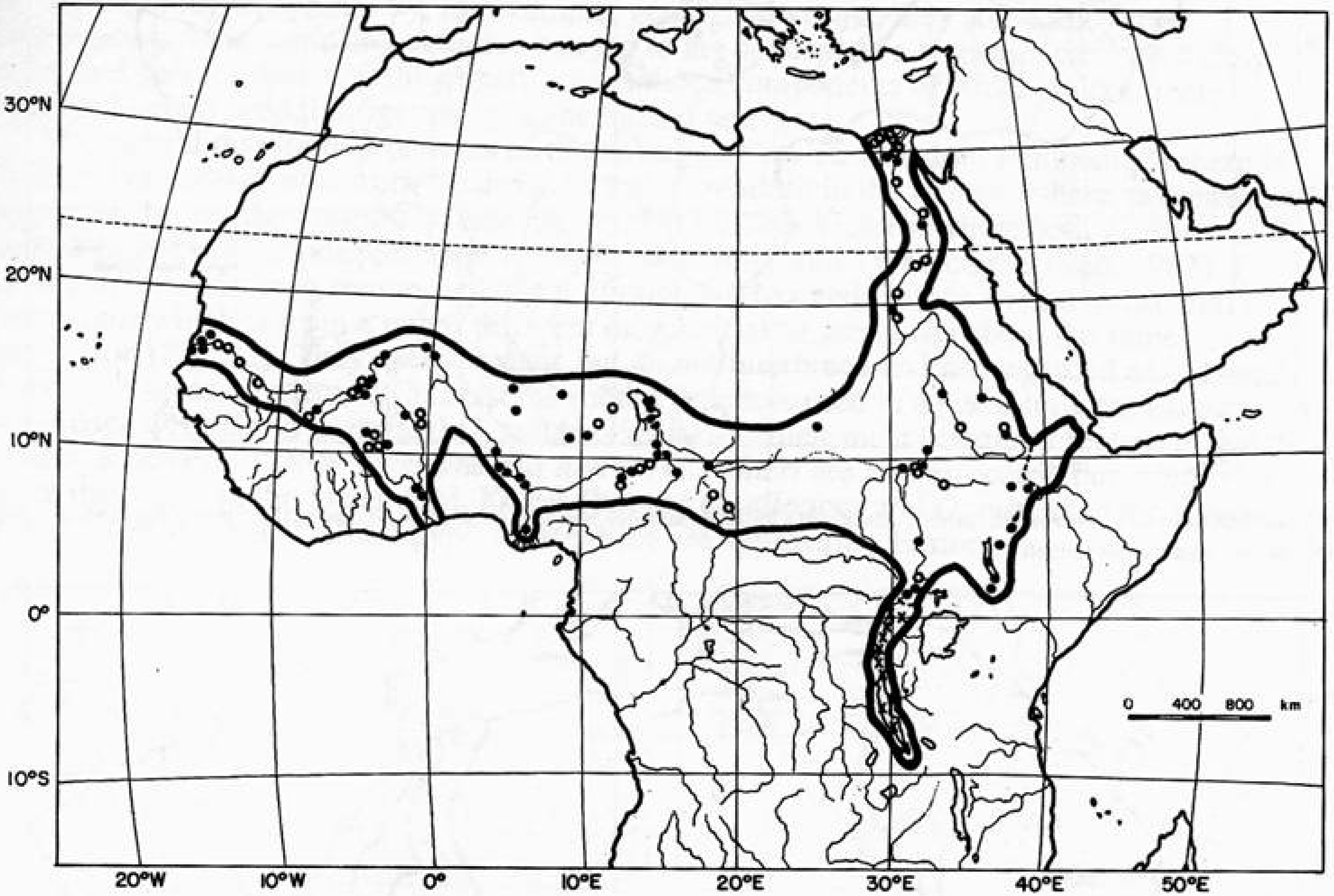
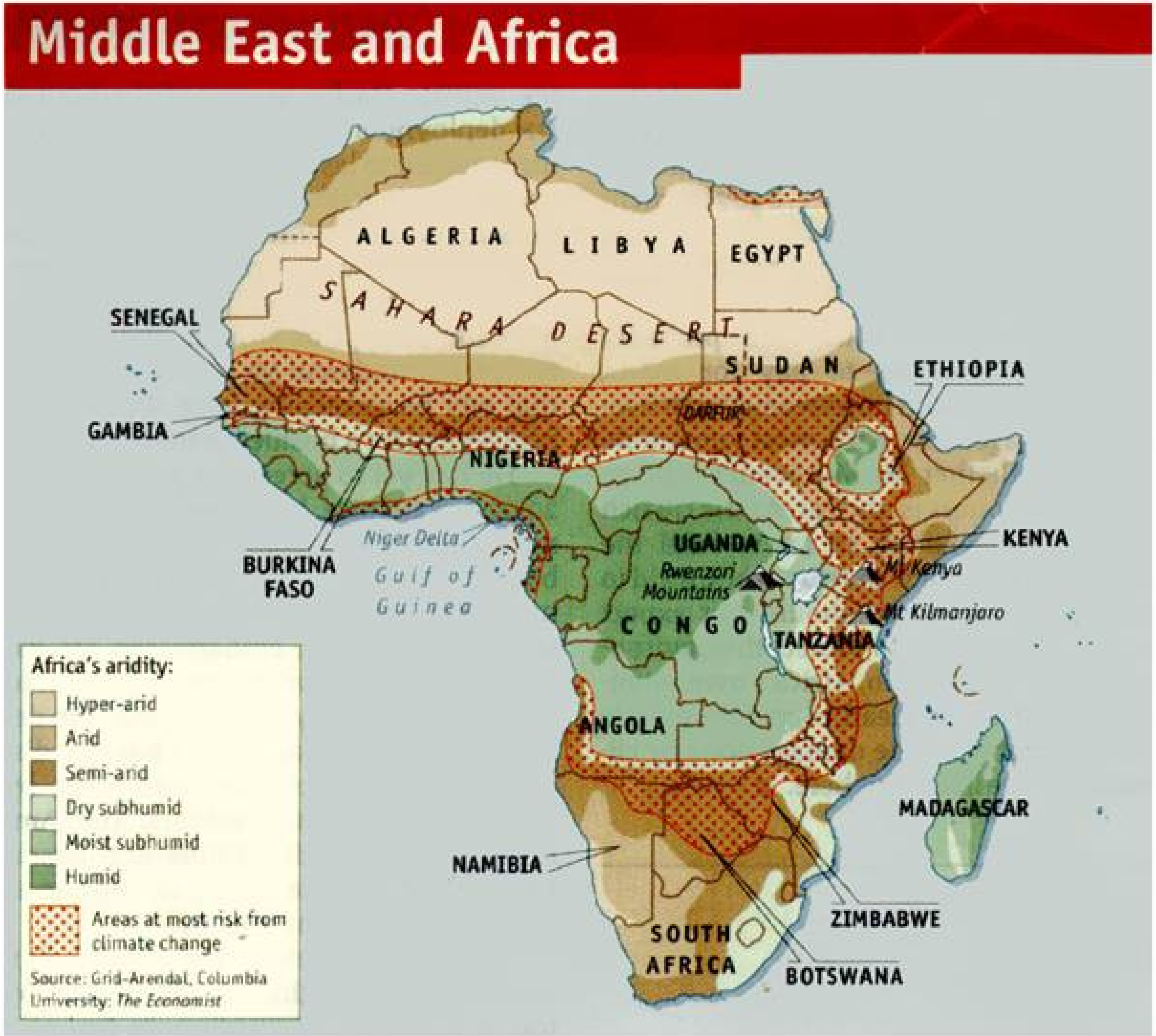
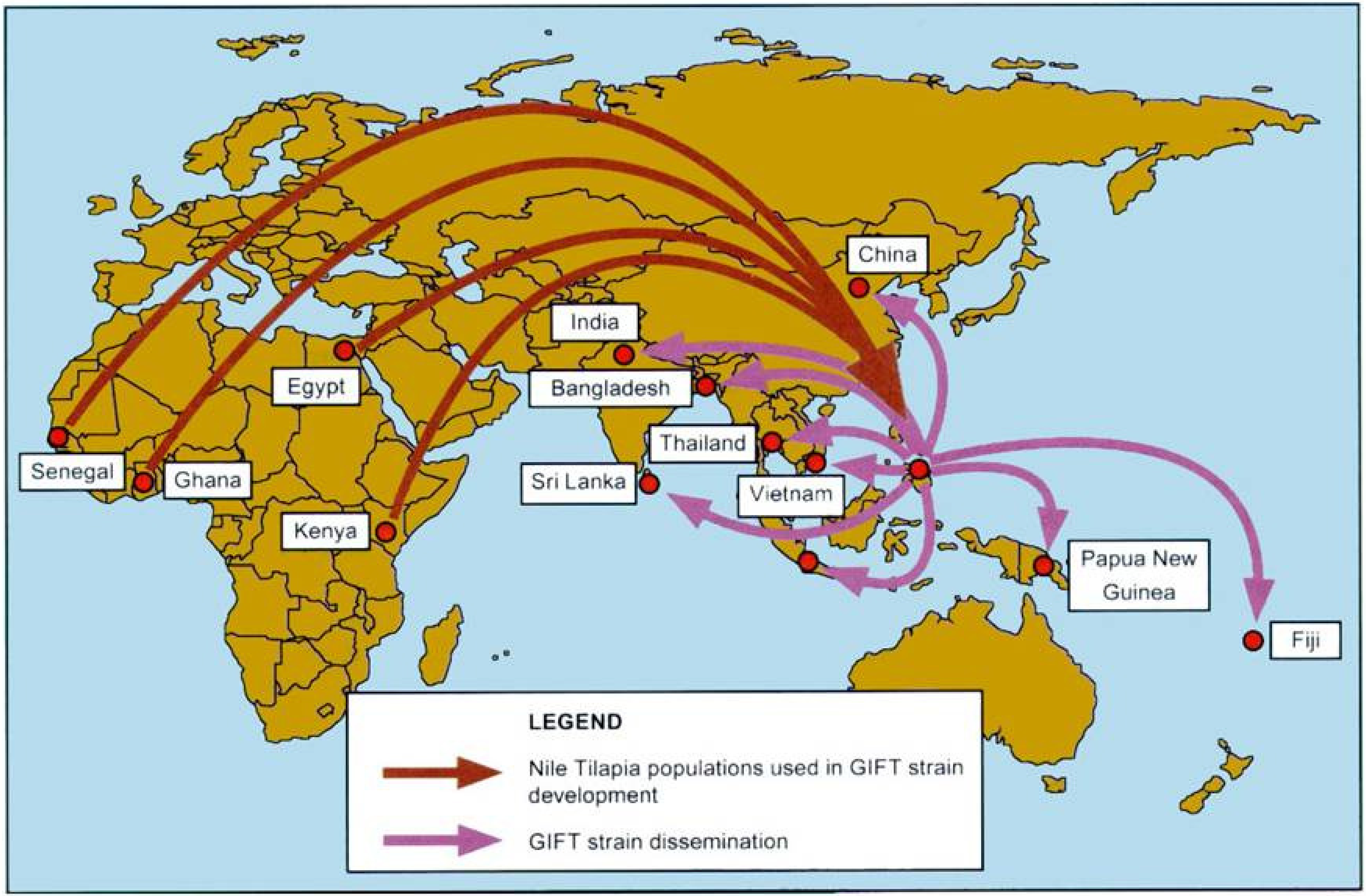


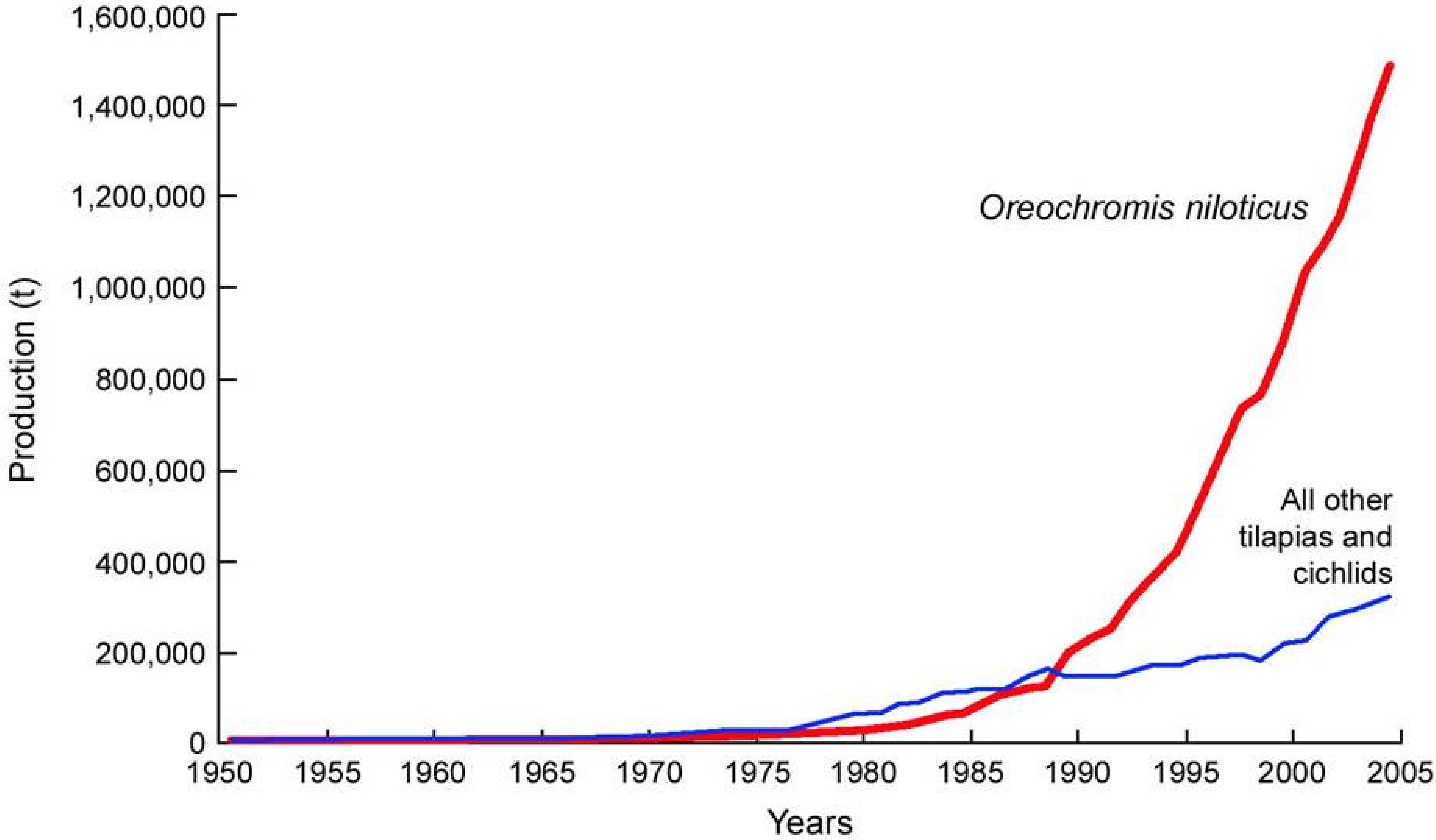
Fig. 8. Distribution of *Oreochromis niloticus niloticus:* black dots (•) indicate samples checked personally by the author; white dots (○) indicate published records regarded as reliable. Distribution of the subspecies *O.n. eduardianus* (x) is also shown. (cf. p. 15 and Appendices I and III – Editor).


Middle East and Africa
ALGERIA
LIBYA
EGYPT
SAHARA DESERT
SUDAN
DARFUR
SENEGAL
GAMBIA
ETHIOPIA
NIGERIA
BURKINA FASO
Niger Delta
Gulf of Guinea
UGANDA
KENYA
Rwenzori Mountains
Mt Kenya
Mt Kilmanjaro
CONGO
TANZANIA
ANGOLA
MADAGASCAR
NAMIBIA
ZIMBABWE
SOUTH AFRICA
BOTSWANA
Africa's aridity:
Hyper-arid
Arid
Semi-arid
Dry subhumid
Moist subhumid
Humid
Areas at most risk from climate change
Source: Grid-Arendal, Columbia University; The Economist


China
India
Bangladesh
Egypt
Senegal
Ghana
Kenya
Thailand
Sri Lanka
Vietnam
Papua New Guinea
Fiji
LEGEND
Nile Tilapia populations used in GIFT strain development
GIFT strain dissemination

GIFT Breeding Hapas

GET-EXCEL (GIFT x FAST)



1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Production (t)
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Years
Oreochromis niloticus
All other tilapias and cichlids

Precipitation

“Climate change will lead to increased precipitation over more than half the Earth’s surface and this will make more water available to society and ecosystems (medium certainty)”

“Under the MA scenarios, water availability is projected to decrease in 30% of the world’s rivers…largely the result of climate change… For the 110 modeled basins that are drying, the basin–specific percentage of fish species likely to face extinction ranges from 1% to 60% for 2050 and from 1% to 65% for 2100 (low certainty)”

(MEA 2005b)

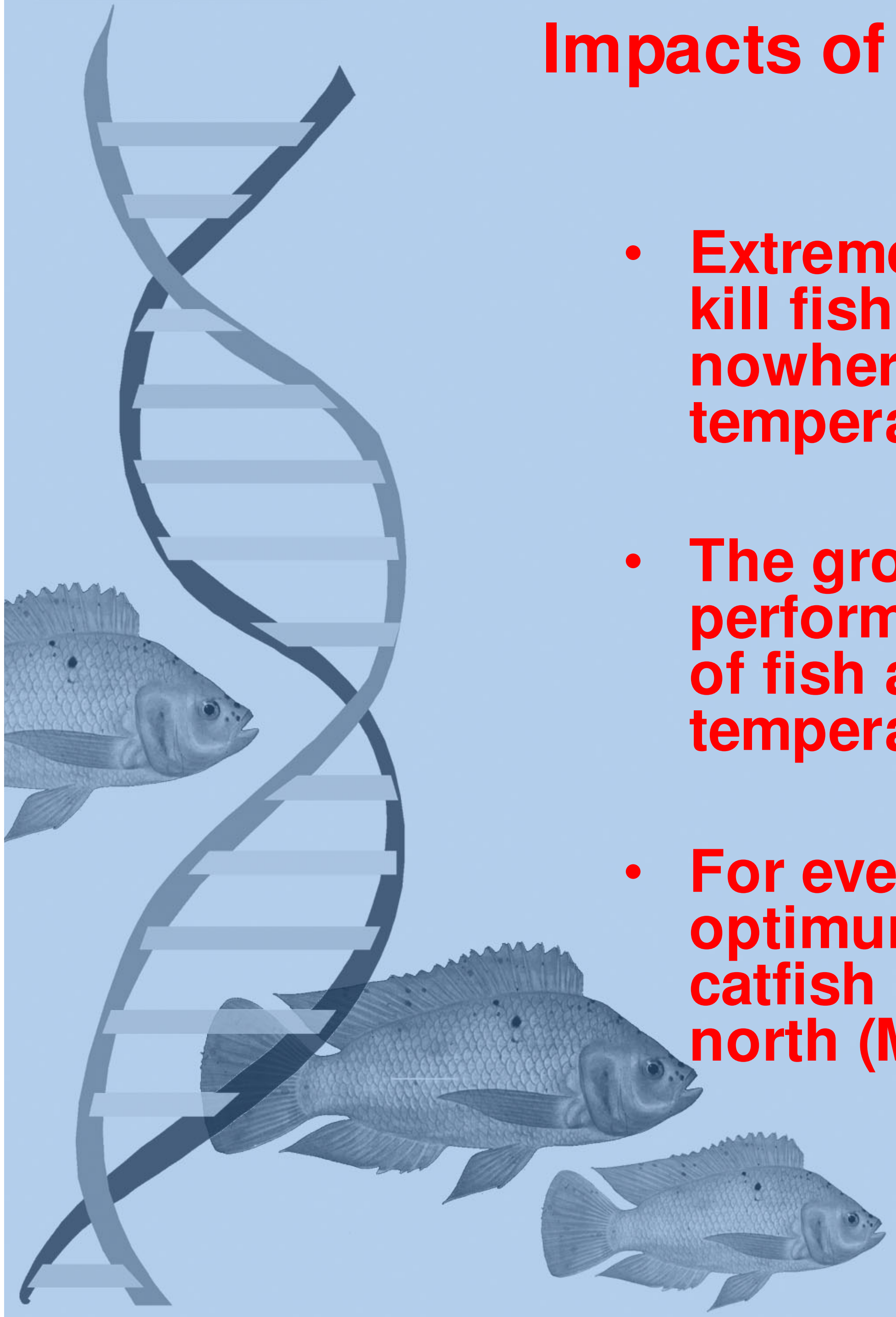
Water Demand in 10 Major River Basins

For 10 major river basins, representing about 30% of all irrigated lands - Amazon-Tocantins (A); Congo; Danube (D); Ganges; Indus; Euphrates-Tigris (ET); Mekong (M); Missouri-Mississippi; Volga; and Yangtze – the overall picture is: increased water demand; water shortages (especially for A, D, ET and M) and increased reliance on small streams and small tributaries to maintain flows (Muttiah and Wurbs 2005)

Higher Water Temperatures

***" Higher inland water temperatures may reduce the availability of wild fish stocks by harming water quality, worsening dry season mortality, bringing new predators and pathogens and changing the abundance of food available…."*(WorldFish 2007)**

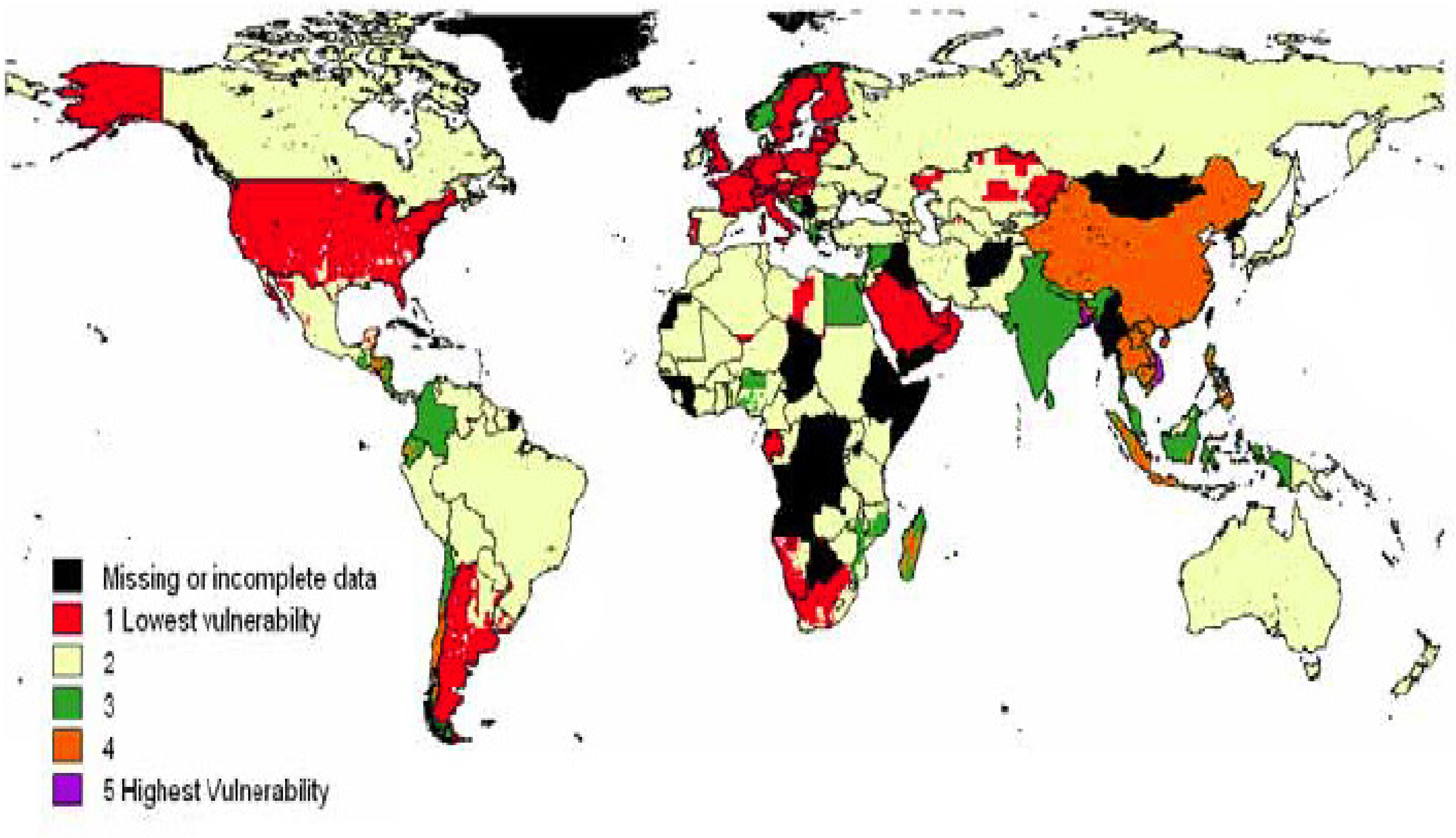
Impacts of Temperature Change



- **Extreme, not average, temperatures kill fish! Freshwater fish often have nowhere to go to avoid adverse temperatures/less oxygen**

- **The growth, maturation, reproductive performance and immune response of fish all vary with ambient temperature**

- **For every 1.0 deg. C rise, the optimum range for farming channel catfish in N. America will shift 240km north (McCauly and Beitinger, 1992)**



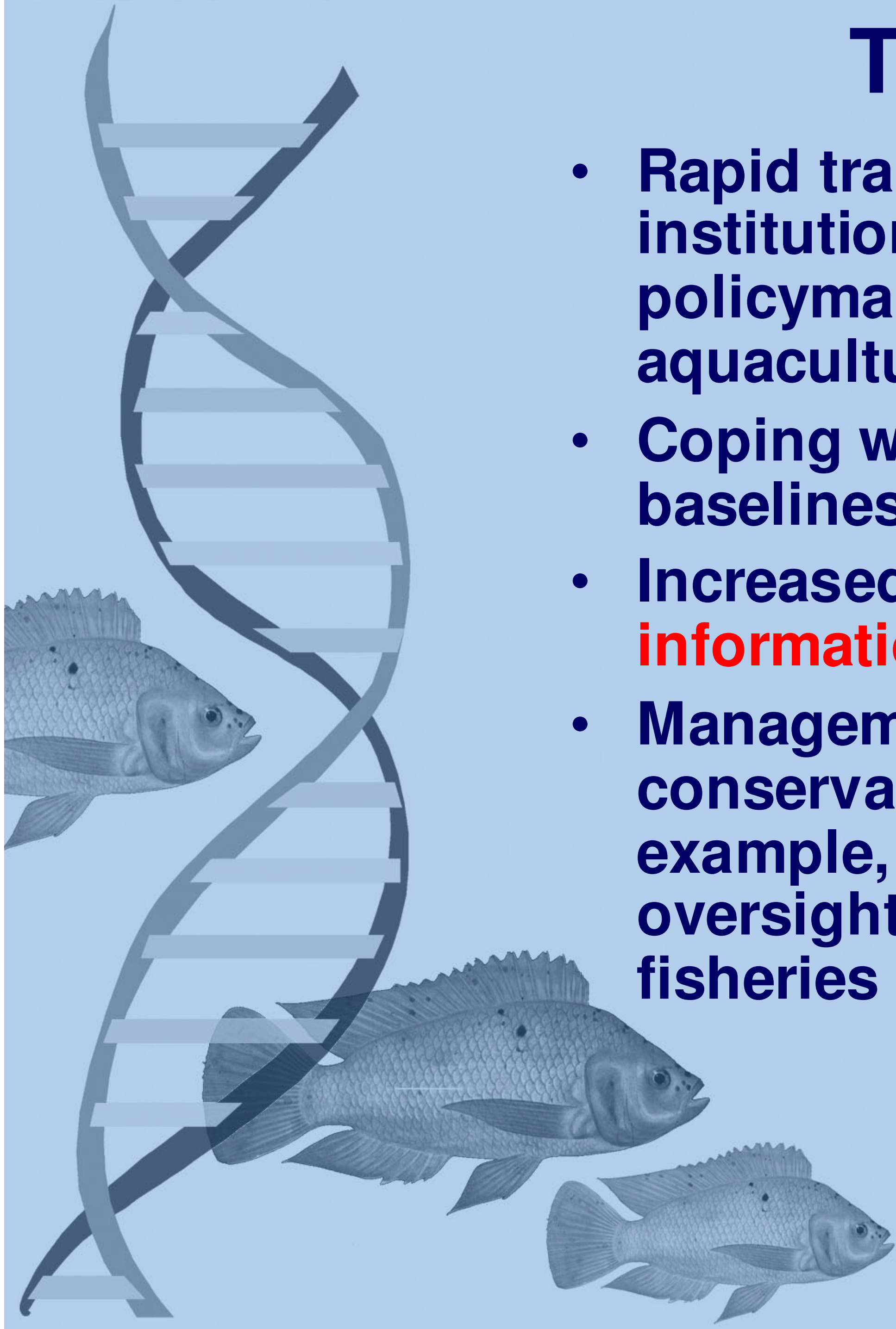
Vulnerability with main emphasis on areas where aquaculture makes a significant contribution to the economy (layer 18).

(Source: Handisyde et al. 2006)

Current and Plausible Future Trends for the Impacts of Climate Change on Wetlands, Under Different MA Scenarios for Ecosystem Management

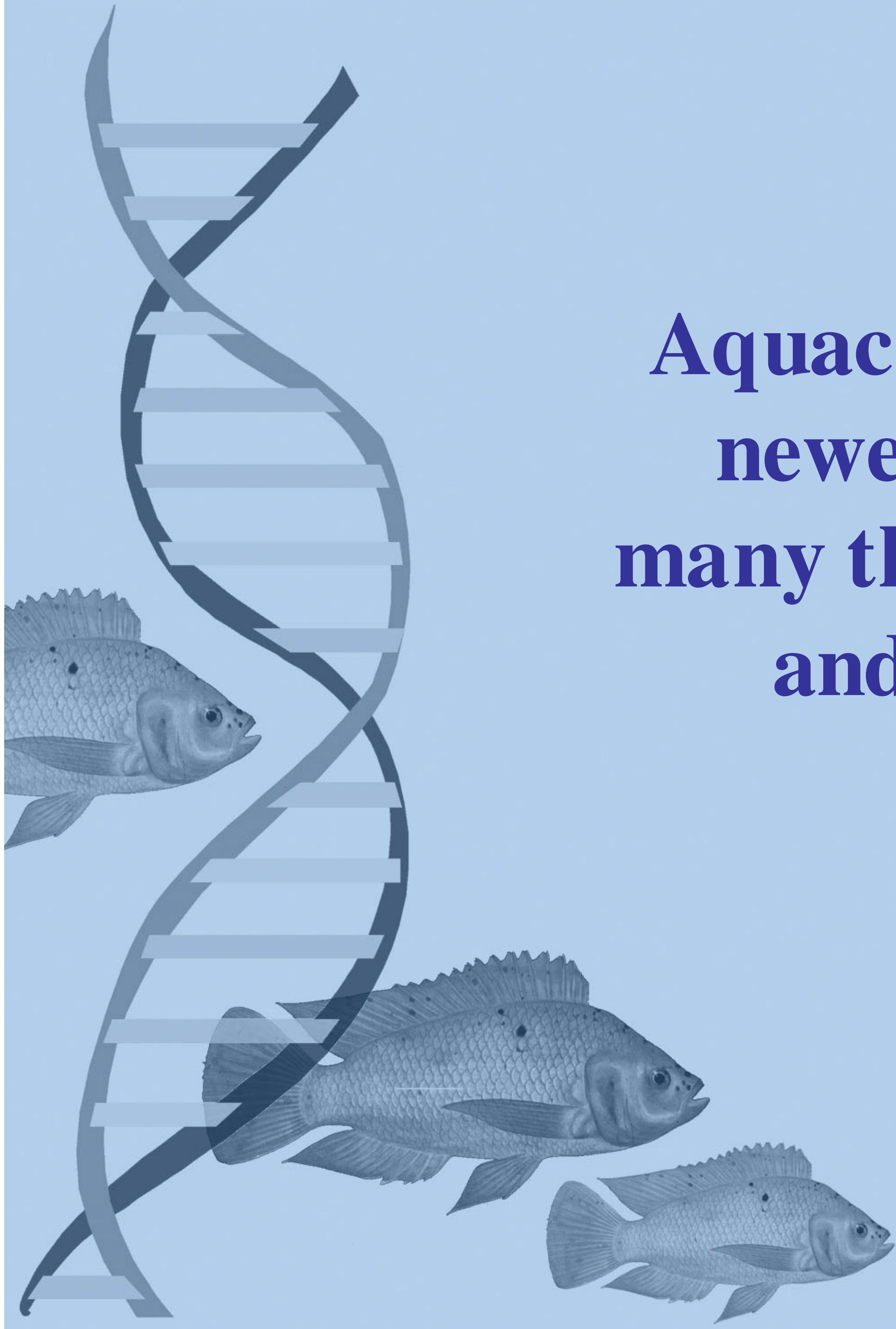
Scenarios	Trends: Current	Trends: Future
1. Globalized/ Reactive: "Global Orchestration"	Continuing	Very rapidly increasing
2. Globalized/ Proactive: "TechnoGarden"	Continuing	Increasing
3. Regionalized/ Reactive: "Order from Strength"	Continuing	Increasing
4. Regionalized/ Proactive: "Adapting Mosaic"	Continuing	Increasing

(Source: MEA 2005e)

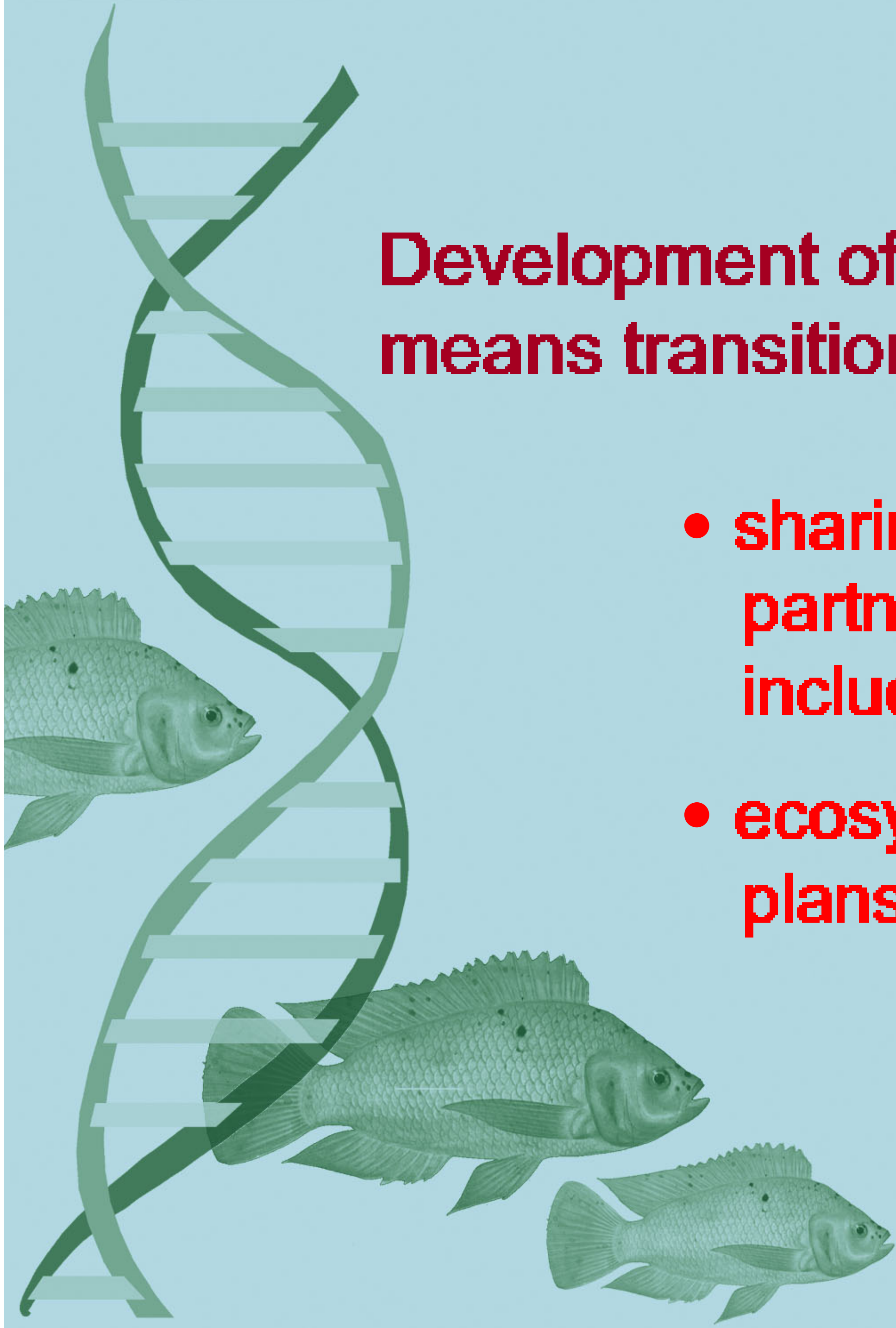


The Future

- **Rapid transition to intersectoral thinking institution building, planning, and policymaking for responsible agriculture aquaculture, forestry etc.**
- **Coping with uncertainty - ‘shifting baselines’**
- **Increased investment in research and information systems**
- **Management as fully integrated conservation and use of FiGR; for example, ‘twinning’ development and oversight of inland aquaculture and fisheries with FiGR conservation**



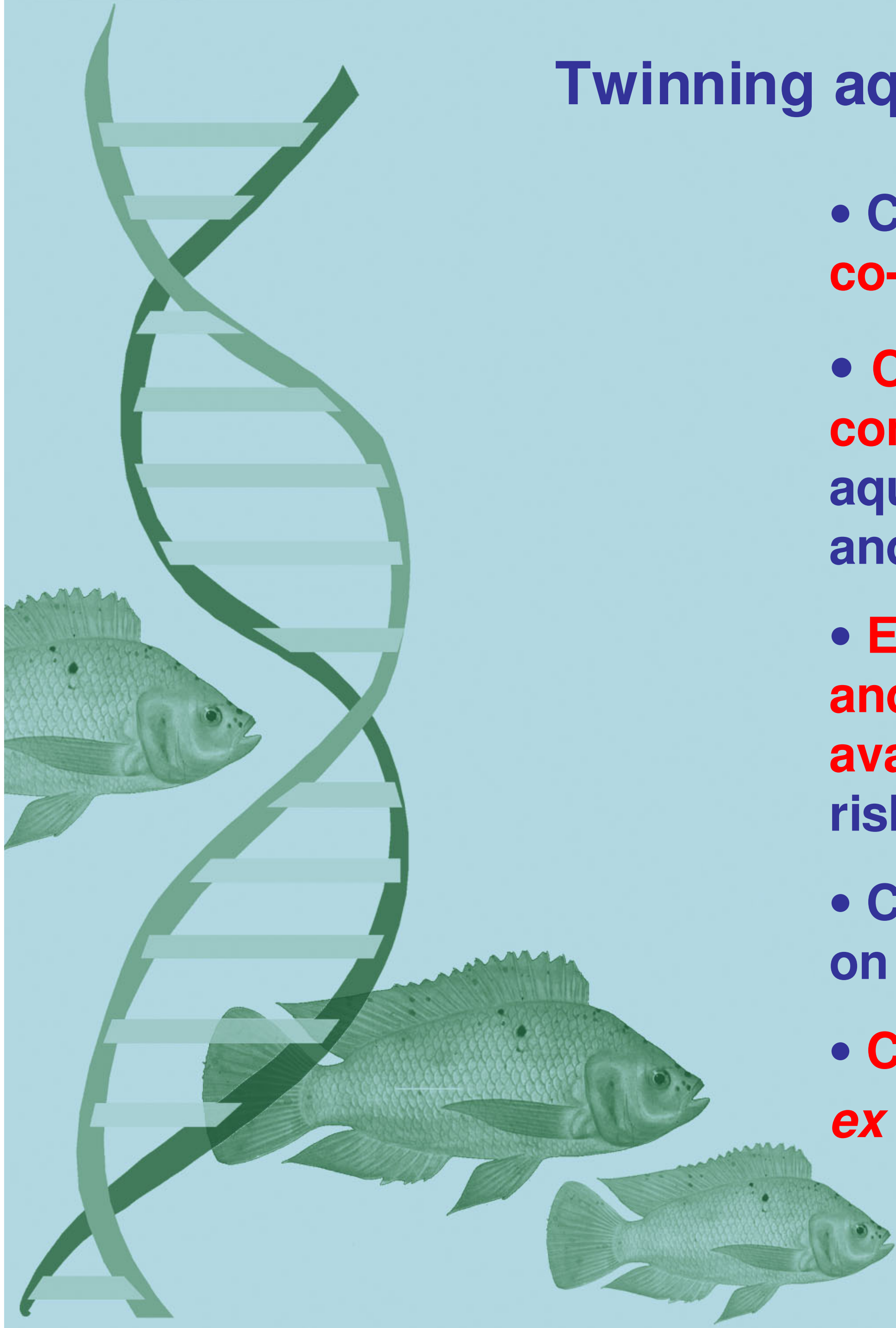
Aquaculture is often the newest sector among many that use land, water and other natural resources



Development of responsible aquaculture means transitions to:

- sharing natural resources in partnerships with other sectors, including nature conservation
- ecosystem-based policies, plans and projects

Twinning aquaculture/FiGR conservation



- Co- policymaking, co-planning and co-financing
- Conservation of wild FiGR *in situ* in conservation zones, off-limits to aquaculture/ isolated from farmed fish and farm waters
- Establishment of aquaculture zones and farming there the best fish available, while avoiding environmental risks
- Conservation of farmed FiGR *in situ* on farms
- Conservation of wild and farmed FiGR *ex situ*, as necessary

(Pullin 2007)

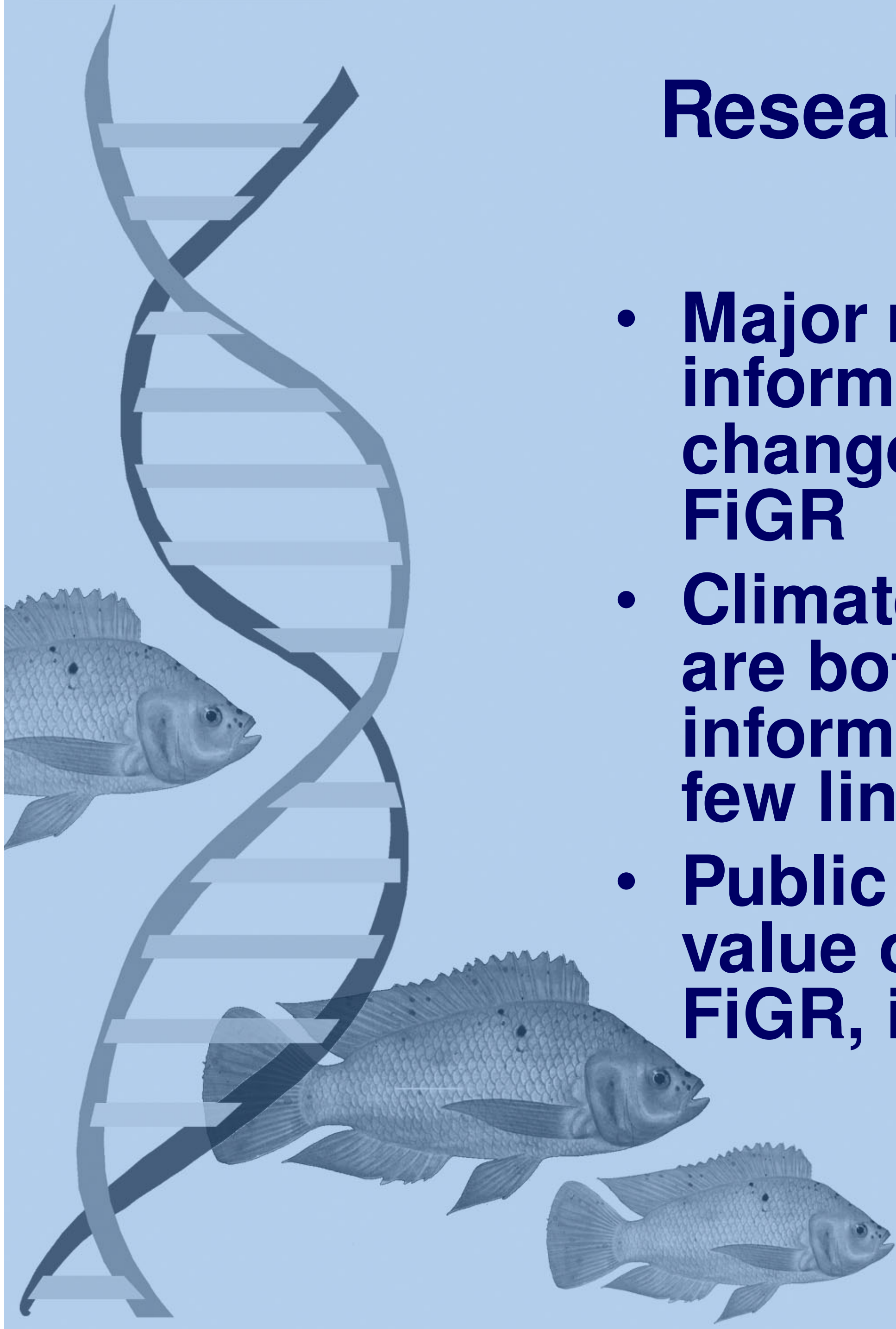
Ex situ/In Vivo/In Vitro Gene Bank

GIFT *Ex situ/In Vivo* Gene Bank

Sampling GIFT semen

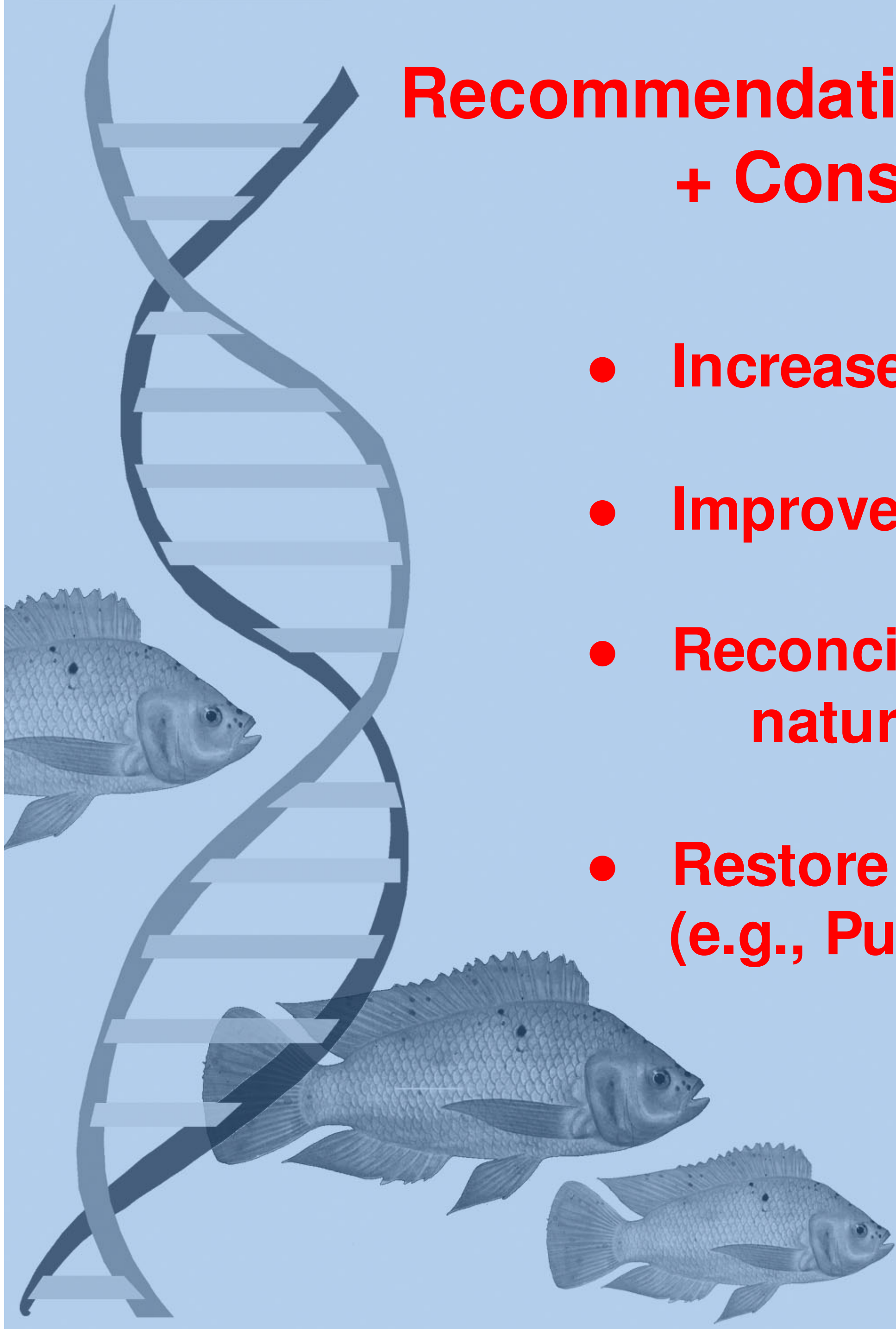
Diluting GIFT semen

GIFT *Ex situ/In Vitro* Gene Bank



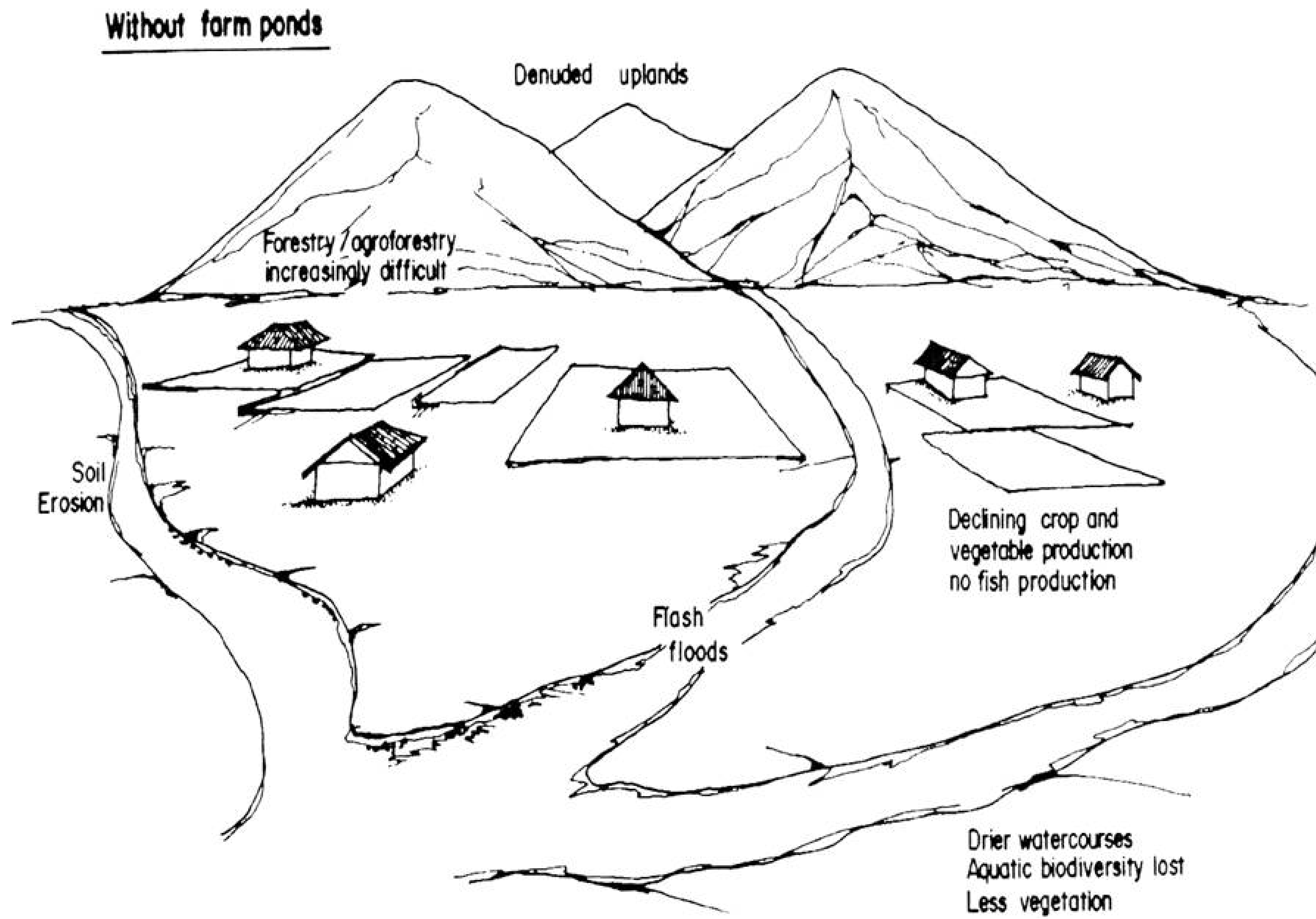
Research and Information

- Major research agendas and information systems on climate change have almost nothing on FiGR
- Climate change and aquaculture are both major research and information areas but with very few links between them so far
- Public awareness about the value of FiGR, especially wild FiGR, is lacking

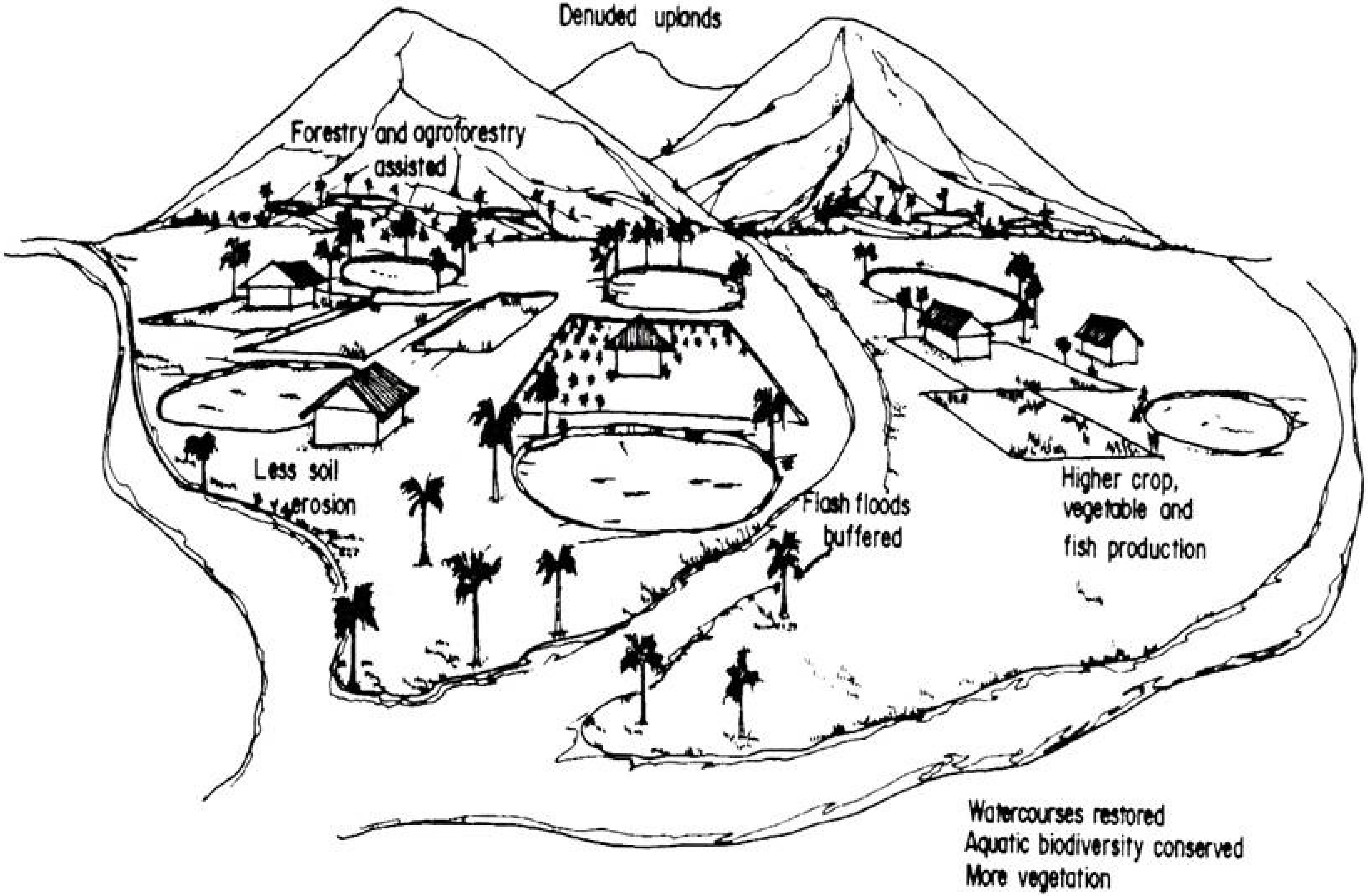


Recommendations for Management (Use + Conservation) of FiGR

- Increase investment
- Improve information systems
- Reconcile (TWIN!) aquaculture and nature conservation
- Restore ecosystems (e.g., Pullin and Prein, 1995)


Without farm ponds
Denuded uplands
Forestry / agroforestry
increasingly difficult
Soil
Erosion
Flash
floods
Declining crop and
vegetable production
no fish production
Drier watercourses
Aquatic biodiversity lost
Less vegetation

With farm ponds



Thank You!