stock enhancement in Sea of Galilee - Israel

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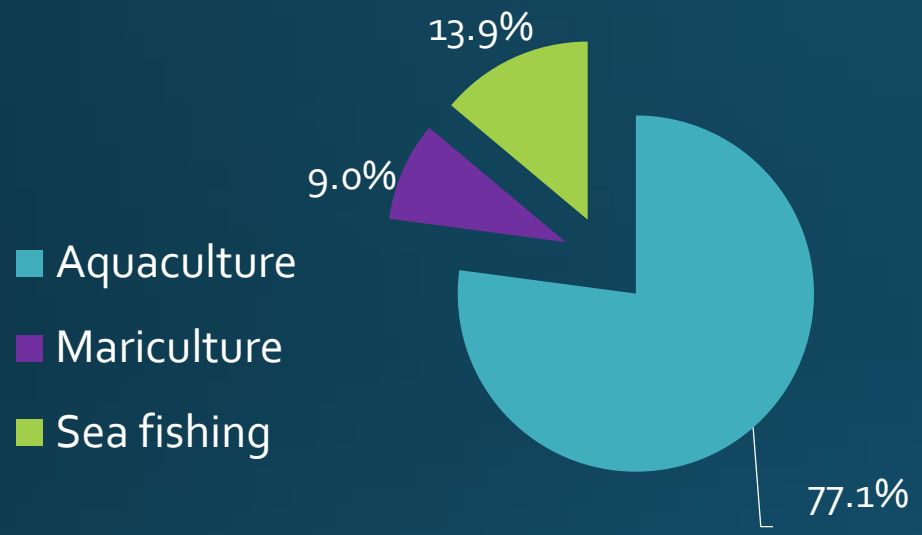
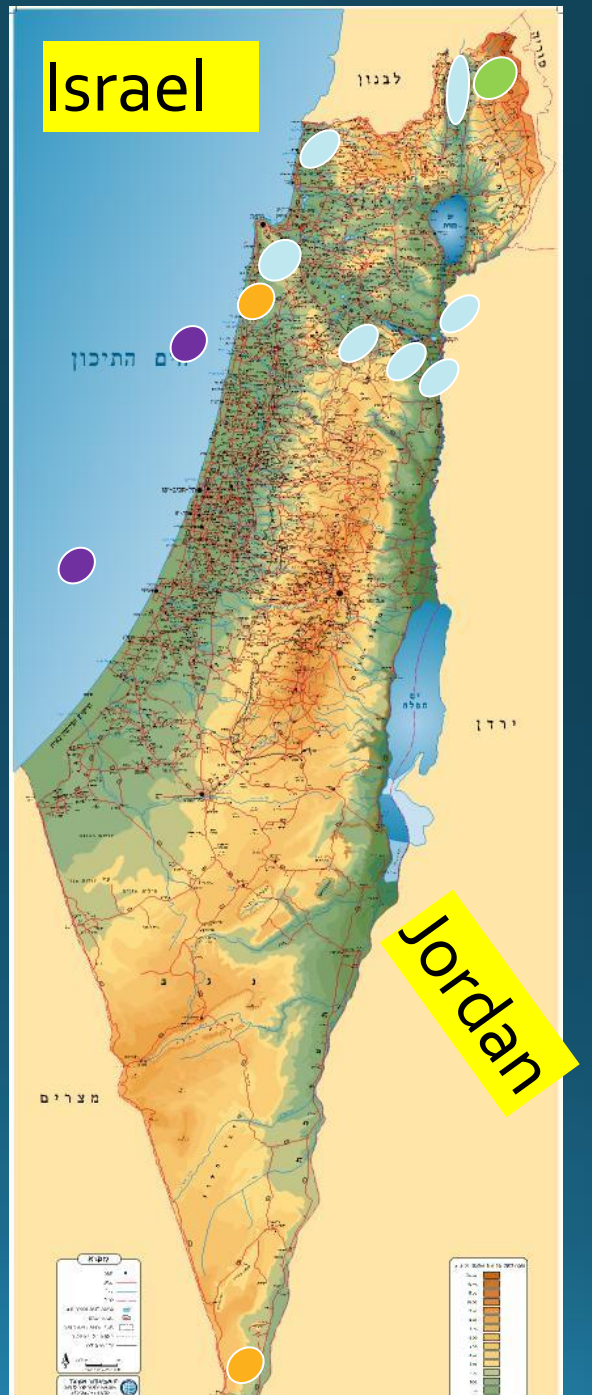
Mote Marine Laboratory, Sarasota, FL USA 14/11/2019

Fish production in Israel

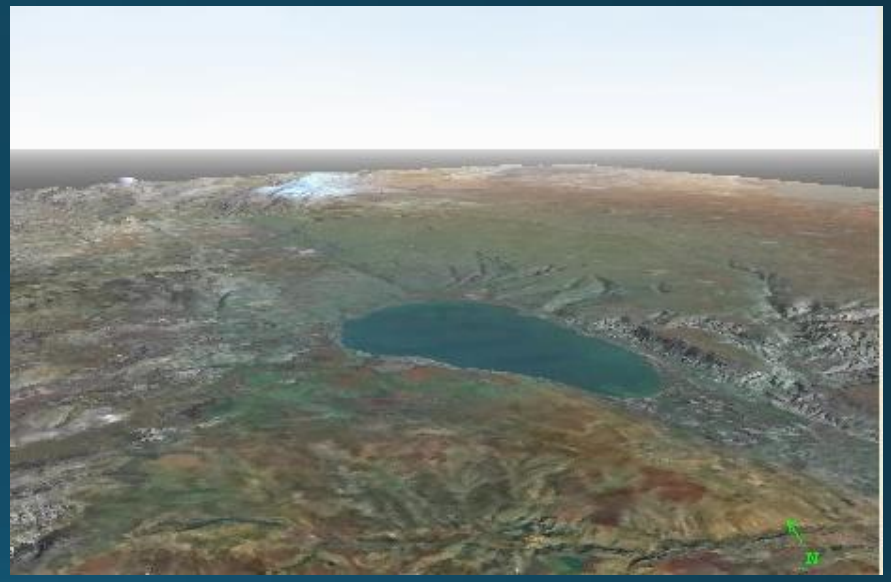


- Conventional fresh water farms
- Trout and sturgeon farm
- Mari culture farms
- Institute for fingerlings production



Sea of Galilee / Lake Kinneret / Lake Tiberius

- The lowest freshwater lake in the world - more than 200 meters below sea level.
- Serves as a source of drinking water for Israel & Jordan



Surface area – 17,000 ha

21 km long

12 km wide

Sea of Galilee - Christian holy site

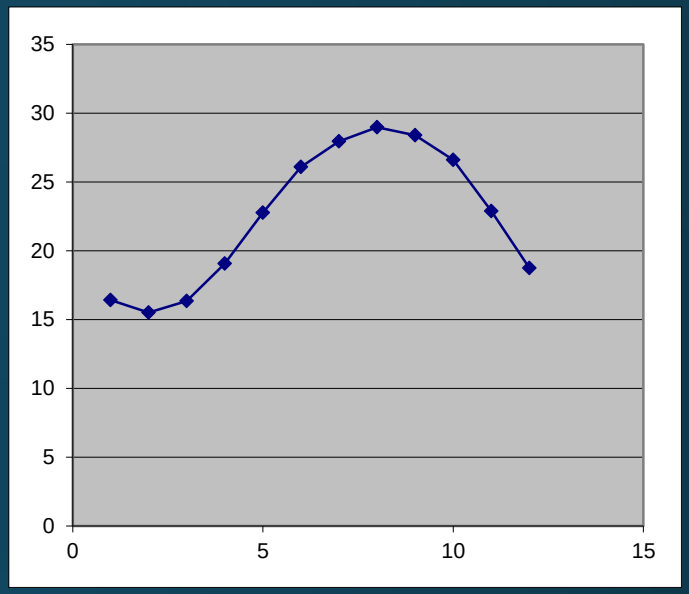
Ecosystem stability

Closed ecosystem

- Seasonal changes in Temp & water level (Evaporation)

Average temp

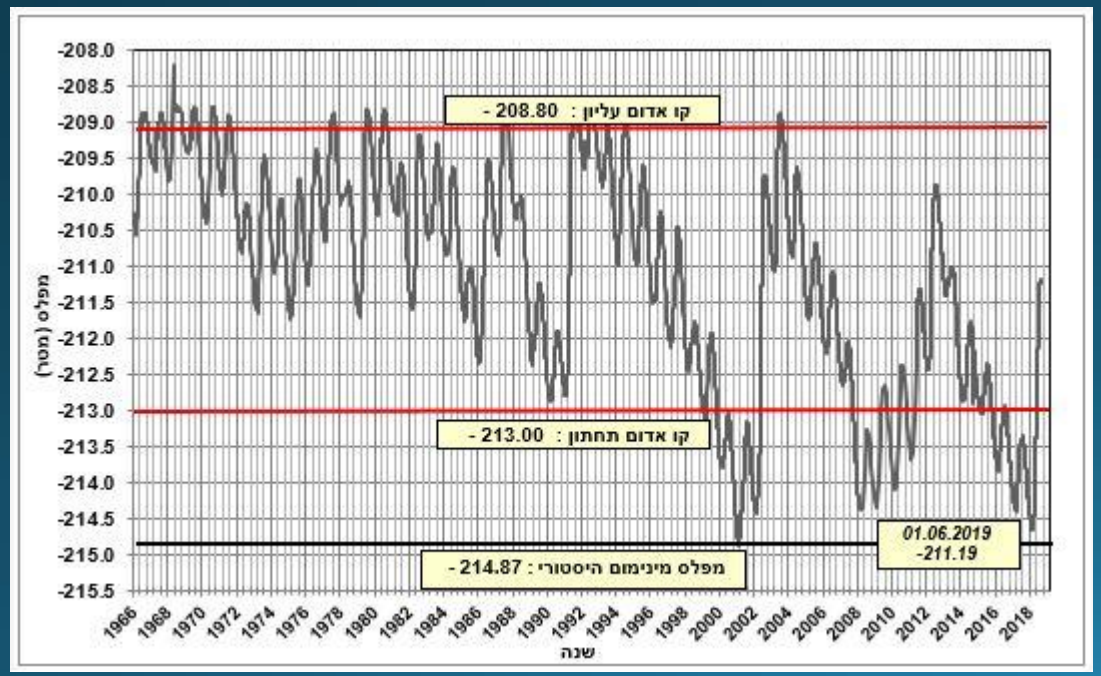
Temp °C



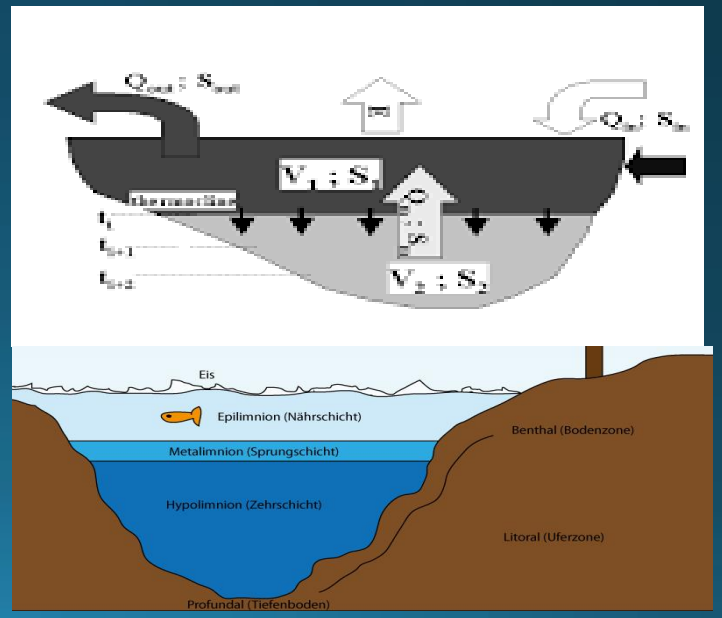
month

The water level

(meters)



Thermal lying

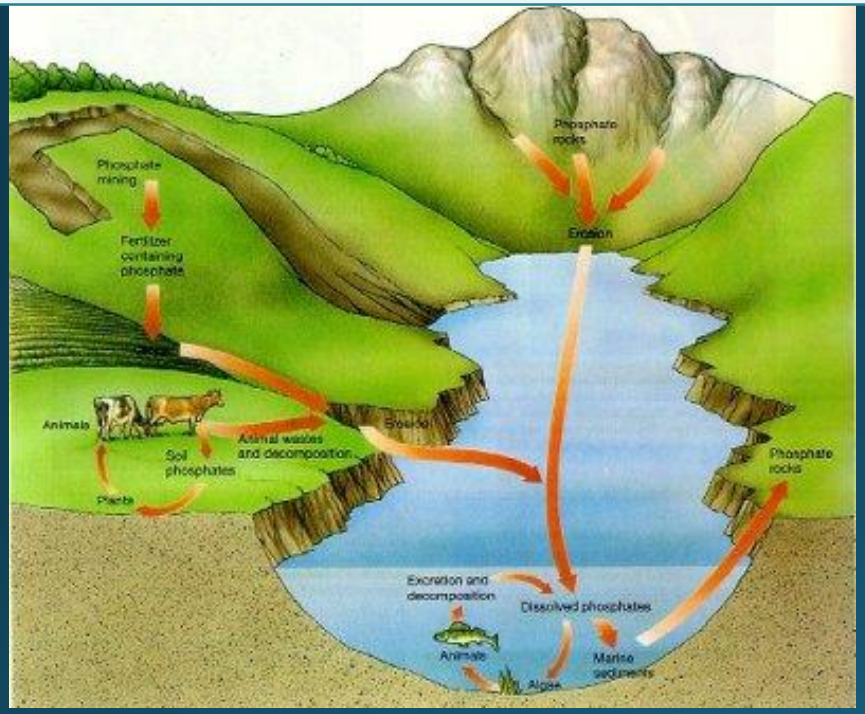


Ecosystem stability

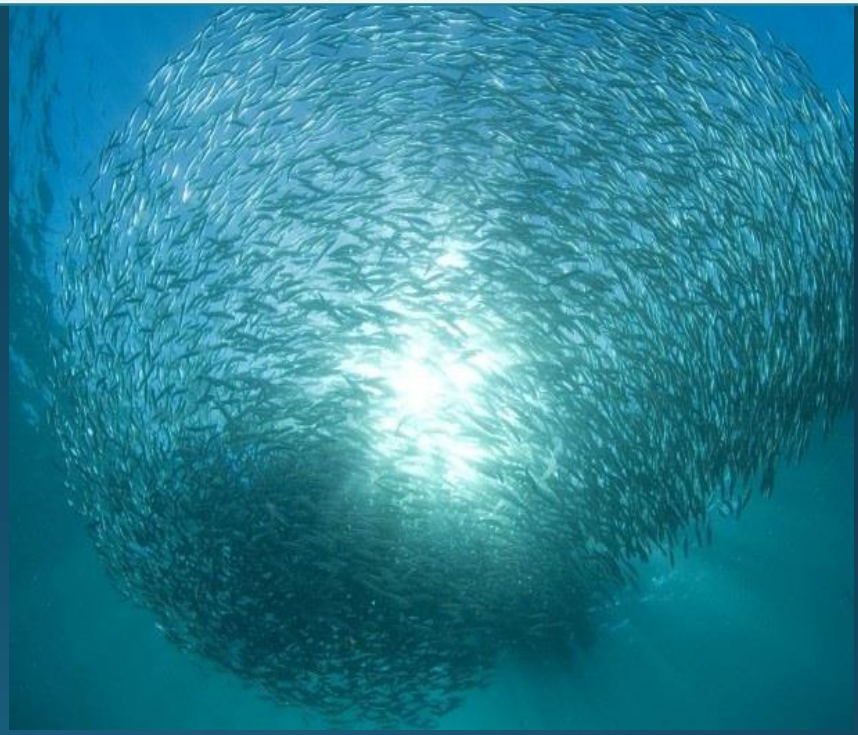
- Bird Migration
- Nutrient flow

The importance of fish in Sea of Galilee ecosystem

Removing phosphorus from the ecosystem



Phosphorus – can be a limiting factor of Primary production in Lakes (Consumed by algae)



Fish biomass - the most effective tool to remove phosphorus from the water

Positive government intervention stocking fish to the lake

Ecosystem balance

Increasing fish harvest

What and **how** to stock is determined by an inter-ministerial professional committee

WATER AUTHORITY

Ministry of Agriculture & Rural Development

THE HEBREW UNIVERSITY OF JERUSALEM

Tiberias fishermen Chairman

TEL AVIV UNIVERSITY

Regulations – Fisheries Supervision

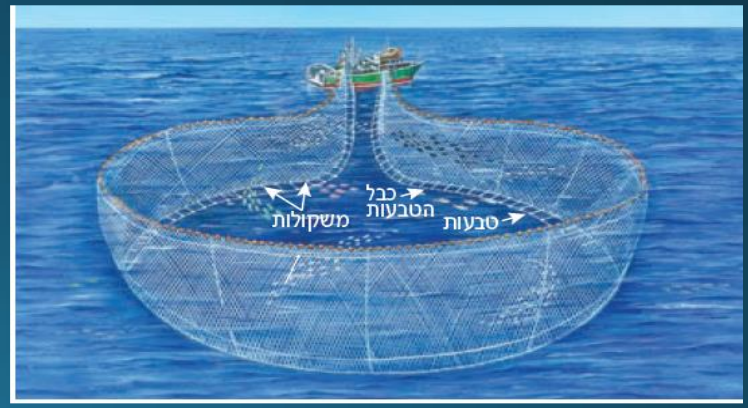
Approved Fishing methods

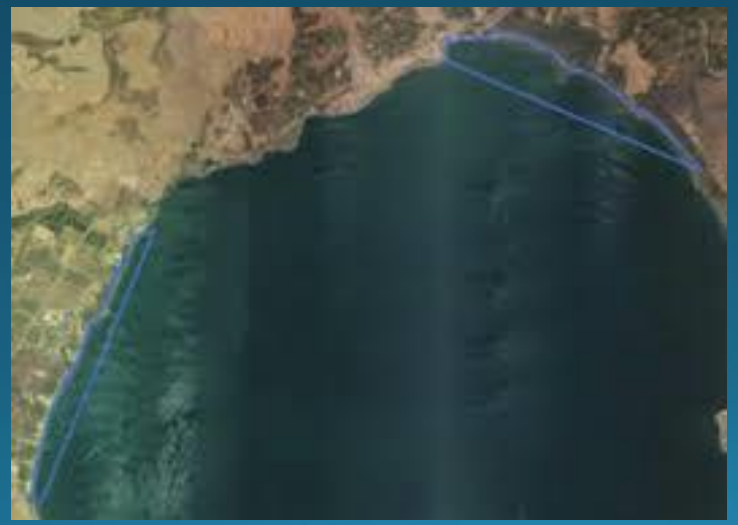
Closing fishing areas during breeding seasons

Supervision & enforcement

Gills net

Chinchula/ sakaleva





fry's supply

Fresh water fish:

Tilapia

Carp

- **Sea water fish:**
  - **Mugil cephalus**
  - Sea bass
  - Sea bream
  - Hybrid stripe bass
  - Red drum
  - Barramundi
  - Experiments: Cobia, Grouper, Flounder

Ecological balance against algal blooms

Algae bloom

Peridinium

Sarotherodon galilaeus

St. Peter's Fish

Sarotherodon galilaeus

- **Ecological Contribution**
  - Feeds on Peridinium algae
  - The algae bloom is an ecological burden
- **Economic value**
  - Very high
  - One of the two most commercial species in Lake Kinneret
- **Reproduction In the Sea of Galilee**
  - Takes place naturally
- **Fry Source**
  - Government Research Station

Is there & What is the effect of the stocking on the genetic diversity in the sea of Galilee?

Historical and recent reductions in genetic variation of the *Sarotherodon galilaeus* population in the Sea of Galilee

Tomer Borovski[1,5] · Roni Tadmor-Levi[1] · James Shapiro[2] · Guy Rubinstein[2] · Seth K. Agyakwah[3] · Gideon Hulata[4] · Lior David[1]

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Abstract
The Sea of Galilee has great significance as a natural habitat and a freshwater source for Israel. Anthropogenic impacts have been placing significant pressure on the species inhabiting this lake, among which is *Sarotherodon galilaeus*, an omnivorous fish with a relatively large population and significance for commercial fishing. An alarming decline in annual catch towards 2008 suggested that this unique population might be at risk. With that in mind, we characterized the current genetic variation of this species in Israel with reference to fish from Ghana, based on D-loop and microsatellite markers. Genetic variation and differentiation were found mostly among fish from Ghanaian localities and between fish from Israel and Ghana, whereas fish from all Israeli localities had uniform and limited variation, a signature compatible with historical founder effect followed by local adaptations. Such historical processes could leave a population vulnerable as reflected in the sudden and recent population decline. Comparing genetic variation between archived 30 year-old scales and modern lake fish revealed further reduction in genetic variation coincident with the recent population decline. Thus, a recently occurring genetic bottleneck had placed this unique and isolated population at an even higher risk. We carefully discuss the events leading to the current risk status for *S. galilaeus* in Israel and highlight the need for vigilant monitoring and active management to support a more sustainable future for this and other fish communities in this important habitat.

Keywords Cichlid fish · St. Peter's fish · Lake Kinneret · Genetic bottleneck · Isolated population · Archived biological samples

Low genetic variation and the decline in population size of *S. Galilaeus* in the Sea of Galilee

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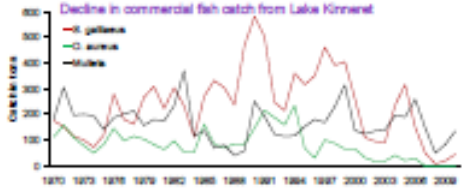
1. Introduction

Sarotherodon galilaeus, also known as "St. Peter's fish", is a medium sized cichlid inhabiting the freshwater Sea of Galilee (Lake Kinneret) in Israel as well as a few more coastal freshwater streams. The lake population is isolated from the coastal populations and from native African populations such as those in Egypt or Ghana. Since this species is commercially fished, the Israeli Ministry of Agriculture reproduces this species in Ginosar station and stocks the lake with fingerlings on a yearly basis. In the last decade, the population size in the lake declined dramatically and several factors, including the low water level, predation by cormorants and over fishing were suggested as possible causes for this decline. We chose to characterize the genetic variability in this species as a possible indicator for the population's wellbeing and as a way to evaluate the effects of stocking.



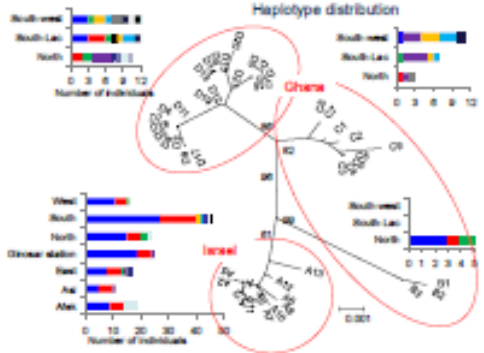
2. Sampling areas and methods

Samples were collected from the lake with local fisherman. Streams were sampled with a Beach seine. Samples from Ghana were kindly provided by the collaborators. DNA was extracted and was used for polymorphism analysis.

mtDNA D-loop sequencing - 250 samples
15 Microsatellite markers – 96 samples

3. D-loop results

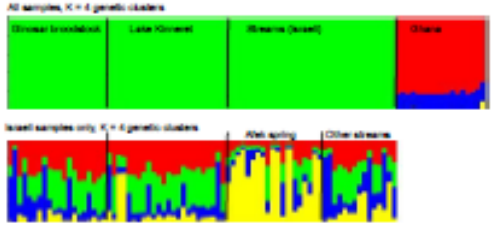
In 1160 base pairs of sequence, we identified 30 polymorphic bases that grouped into 46 haplotypes.



- In Israeli samples, 92% of the individuals had one of two common haplotypes.
- Six out of 30 fish representing the coastal streams had a unique haplotype.
- Ghana samples were polymorphic and different from Israeli samples.

4. Microsatellite results

Individuals were clustered based on their genetic makeup using Structure software. Each individual is a bar colored by the genetic clusters it belongs to.



- All the Israeli fish are genetically uniform and separated from the more variable Ghana fish. Recapitulated the D-loop results.
- In Israeli fish, we could identify a near and slightly different genetic cluster in fish from the Afek spring.

5. Old scales results

We obtained dry *S. galilaeus* scales collected in 1974 – 1989. To analyze the genetic diversity before the decline in catch, a method to extract DNA from old dried fish scales was developed as well as PCR amplification and sequencing.

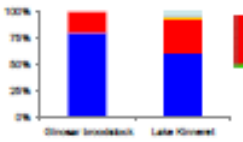
PCR with short D-Loop primers (SGDL4, 118 bp)

- PCR products were successfully sequenced. The sequence aligned well with the D-loop reference sequence of *S. galilaeus*.

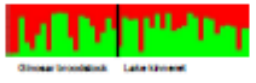
6. Lake Kinneret vs. Ginosar broodstock

To test the effects of *S. galilaeus* stocking from Ginosar to the lake, we looked for markers to identify the two populations.

D-loop haplotype distribution in the two populations



Genetic makeup clustering – microsatellites (K = 2)



- Distribution of the D-Loop Haplotypes was similar between the Lake and Ginosar broodstock.
- Based on microsatellite markers, no differences in the genetic makeup of the two populations could be found.

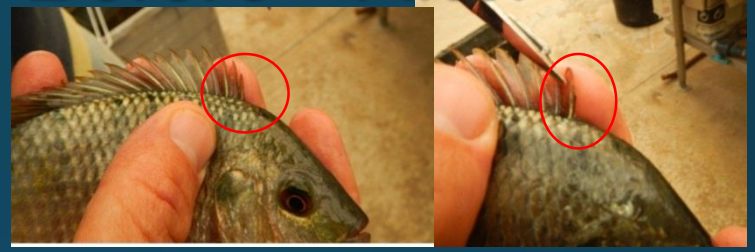
7. Conclusion

- The genetic variation in the Israeli *S. galilaeus* is low compared to the variation in the African populations.
- The results from both mitochondrial and nuclear markers agree well.
- The similarity between the lake fish and the Ginosar broodstock makes it difficult to use genetic markers for evaluation of stocking effects.
- Results from old scales might tell us if the genetic variation in the lake changed over the last 40 years.
- Efforts to increase the genetic variation level might be required.

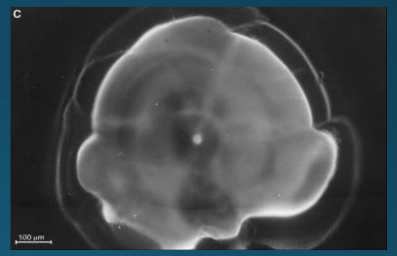
Develop a method for marking *Sarotherodon galilaeus*

- ❑ Cutting Dorsal fin spine

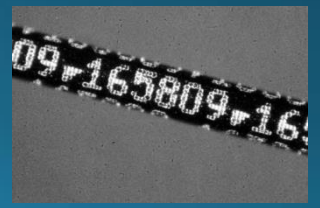
Before *After*



- ❑Chemical – Oxytetracyclin



- ❑Internal tag - CWT (coded wire tags)



marking with CWT in four different areas

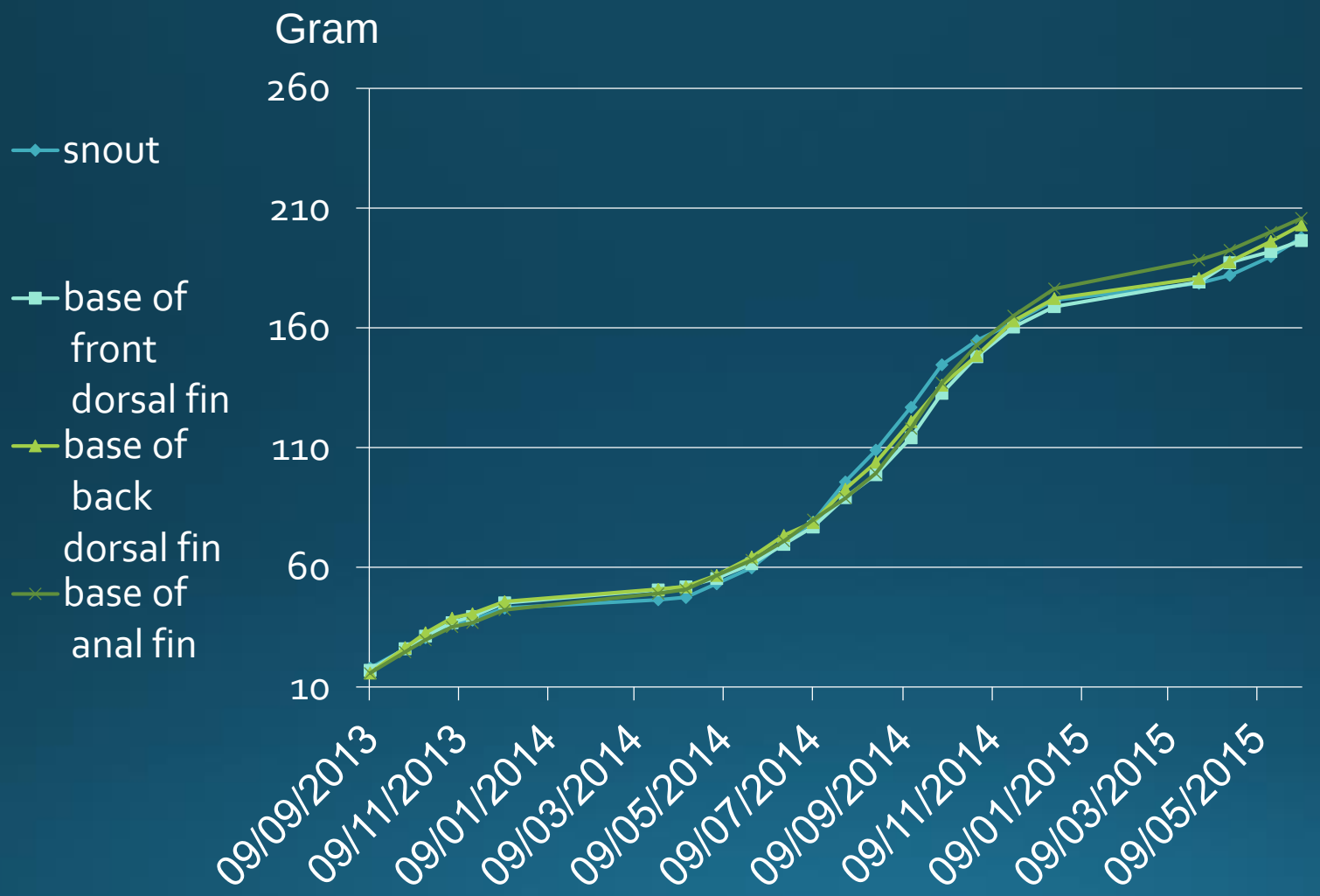
Marking areas tested :

- ❑ Snout
- ❑ Base of Front dorsal fin
- ❑ Base of back dorsal fin
- ❑ Base of anal fin

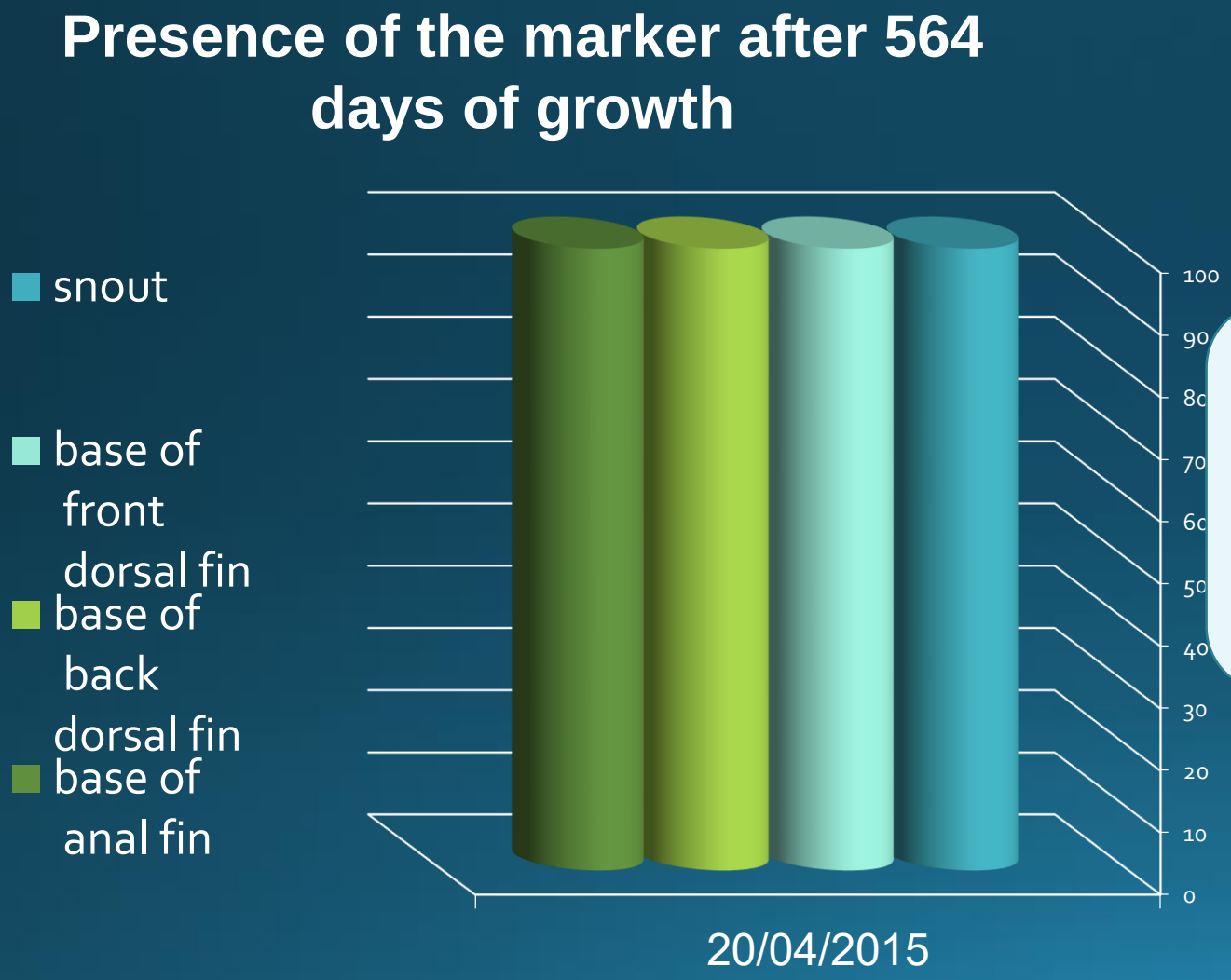



- Four replicates per treatment.
- Number of fish - 20 per a tank, (total 320 fish).
- Feed - on demand, Commercial food, extrusions processed by zemach feed mill.
- Temp - Environment, Lake Kinneret Water .

Fish weight throughout the experiment

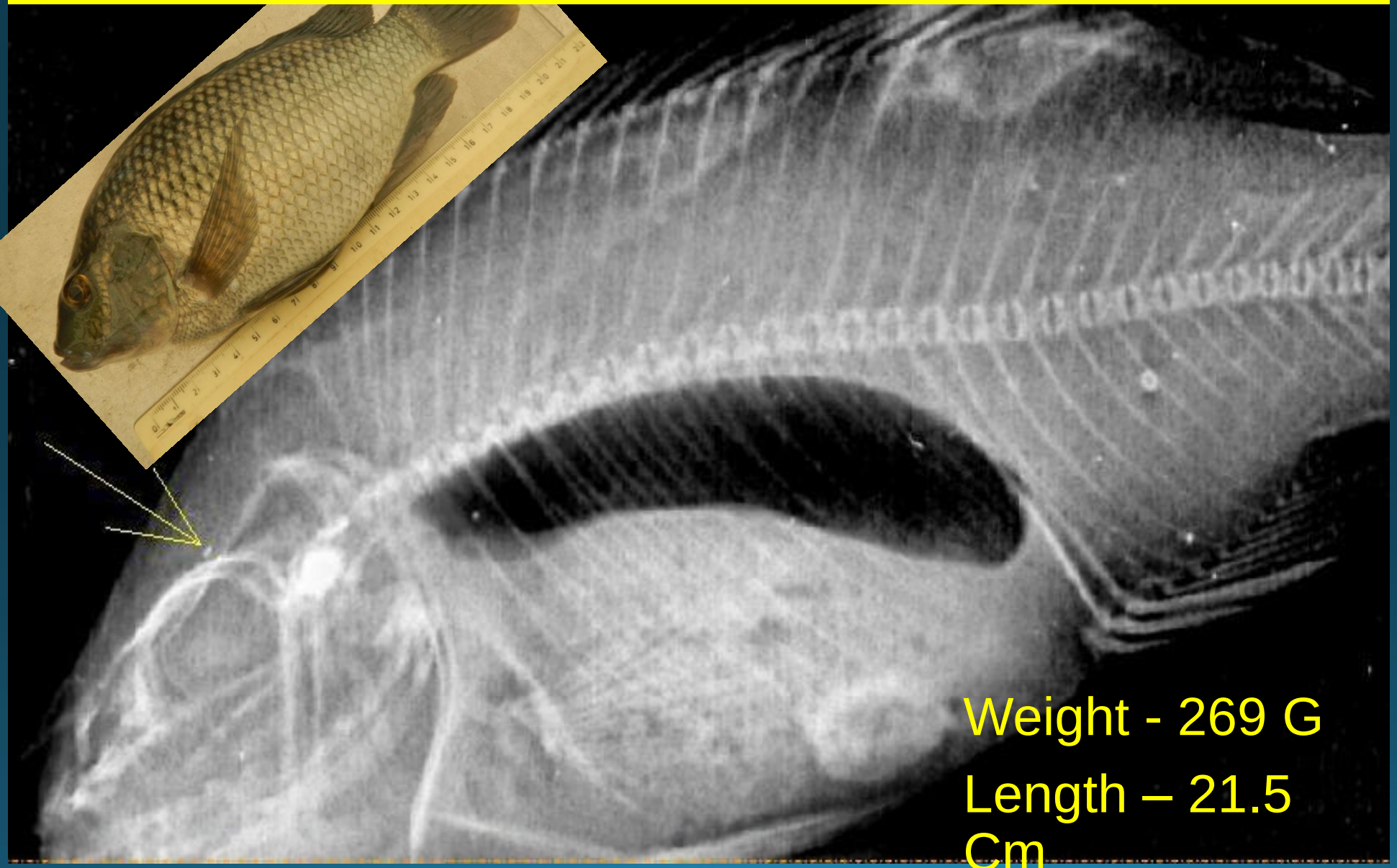


marking with CWT in four different areas - Results



The method was found suitable for marking *Sarotherodon galilaeus*.

Tag Position in the end of the Experiment



Liza ramada
Mugil cephalus

- **Ecological Contribution**
  Humnivor, feeds on detritus from the bottom, and by scraping the top layer of sediment, Increases turbidity.
- **Economic value**
  Very high
  One of the two most commercial species in Lake Kinneret
- **Reproduction In the Sea of Galilee**
  Impossible, require Saltwater
- **Fry Source**
  Collecting from nature (Mediterranean sea) / reproduction institutes

What is the stocking % of survival?

Liza ramada

Mugil cephalus

Fish species	Number of fish (X10³)		% stocked/marked fish
	Stocked	Adult fish that were marked from the lake	
	1995 – 2009	1997 - 2011	
Liza ramada	12,188	3,320	27.2
Mugil cephalus	1,800	513	28.5

Development of genetic markers to distinguish between wild and cultured populations

Our findings indicated a multiplicity of alleles (between 2 and 6 alleles) with an average of 3.8 alleles per marker.

A map of alleles describing the genotype of grey mullet parents pairs

No.	Loci	Allele	Parental per geynotypes	
			For group 1 (n=4)	For group 2 (n=14)
1		1 2	264/264 264/270	264/270 270/270
2		1 2	190/190 198/198	190/198 190/198
3		1 2	200/200 212/222	212/222 212/222
4		1 2	162/166 162/166	162/162 162/166
5		1 2	285/285 285/287	285/285 285/285
6		1 2	185/185 185/185	185/185 185/185
7		1 2	236/236 248/248	236/248 236/236
8		1 2	174/178 178/178	168/174 178/178
9		1 2	228/228 228/228	228/228 228/230
10		1 2	176/176 184/184	176/176 176/176
11		1 2	193/195 199/199	193/195 193/199
12		1 2	152/152 142/152	152/152 152/152

Genetic identification of the fish

Fish weight (grams)	Fish length (cm)	Sampling number	
640	34	Fc5	√
726	39	Fc6	X
624	35	Fc7	X
351	28	Fc8	X
470	31	Fc9	X
524	33	Fc10	X
459	31	Fc11	X
442	31	Fc12	√
662	35	Fc13	√
593	33	Fc14	√

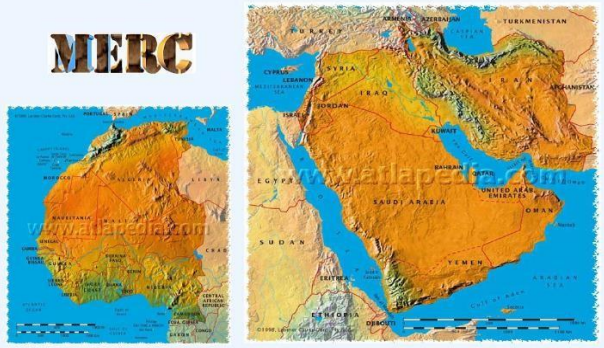
A capability to identify families on a genetic basis was developed

Proof of feasibility of stocking grey mullet fingerlings from breeding institute in the Sea of Galilee

USAID
FROM THE AMERICAN PEOPLE

Middle East Regional Cooperation Program

MERC



Award No.:
SIS70017G33038

Stock enhancement and production of Grey Mullet fry

Coordinator

Mote Marine Laboratory

Florida, USA

Partners

Institut National de Recherche Halieutique

Casablanca MOROCCO

Institut National des Sciences et Technologies de la Mer Salammbô TUNISIA

National Institute of Oceanography and Fisheries Alexandria EGYPT

Israel Oceanographic & Limnological Research

Eilat ISRAEL

Ministry of Agriculture and Rural Development

Tel Aviv ISRAEL

Observer

Annaba University

ALGERIA

Collaborating institute

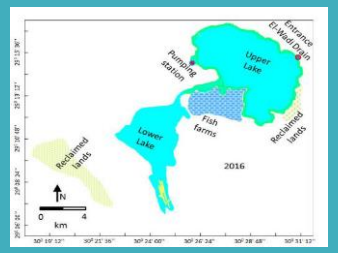
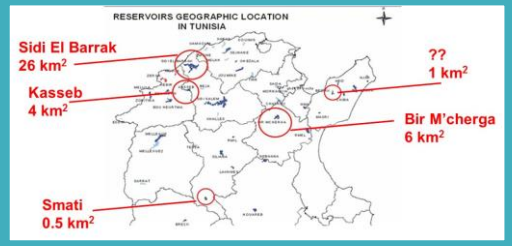
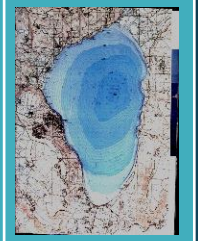
Marine Science Station

Aqaba JORDAN

Project work plans

Work Packages:

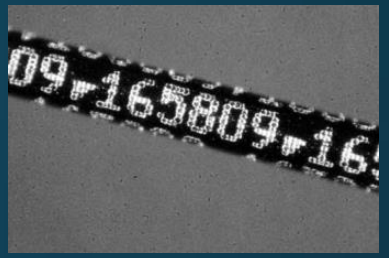
- **Stock enhancement operations**
  Adaptive experiments; Fry transport; Tagging
- **Monitoring results of stocking**
  Sampling to recapture stocked fish for analysis
- **Mullet-aquaculture technology subtasks**
  - Improving mullet juvenile quality
  - Developing local mullet fry feed
  - Larval rearing and ontogenetic development
  - Fry acclimation & growth control in cages
  - Synthesis of protocols & best management practices
- **Training courses for students and technicians**

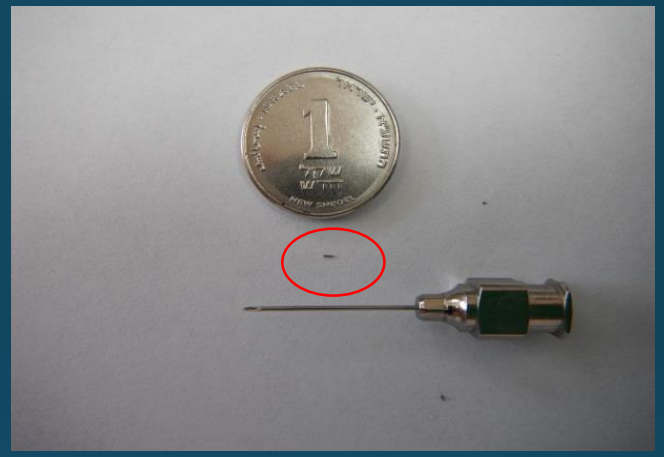
Country		Egypt				Tunisia					Israel
Map\picture				 							
Location		Fayoum area		Alexsandria area		1	2	3	4	5	1
Stoking site		**Wadi El Rayan-Fayoum - Upper**	**Wadi El Rayan-Fayoum - Lower**	**Wadi Mariout area Alex.**	**Nozha marine airport Lake**	**Lebna**	**Bir M'cherga**	**Kasseb**	**Sidi El Barrak**	**Smati**	**Lake of Galilee**
Salinity	ppt	3-4	20	12-32	??						fresh
Size	km2	51	62	50.4	4.8	5	6.3	4.3	26	0.5	167
Mid. no. of stock. Fish	fish #	25,500	31,000	25,200	2,400	2,500	3,150	2,150	13,000	250	83,500

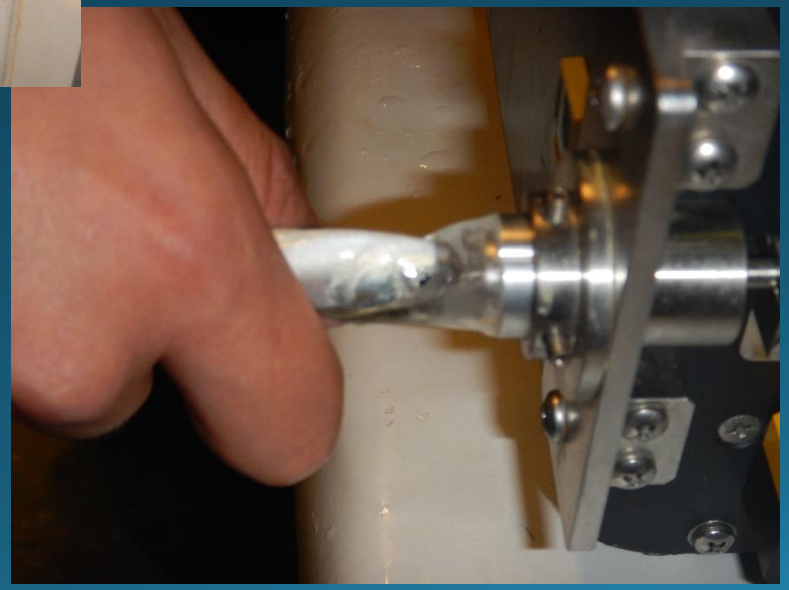
Fish tagging technique

Mugil cephalus

CWT (coded wire tags)



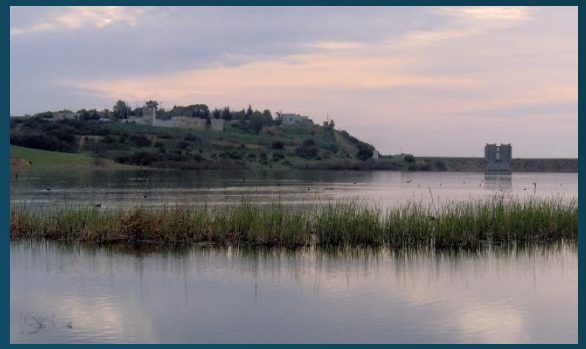




Stocking fry in lakes

In Israel, Egypt

and Tunisia



Collecting for monitoring results

Research questions in Israel part:

1. Fish size at the time of release

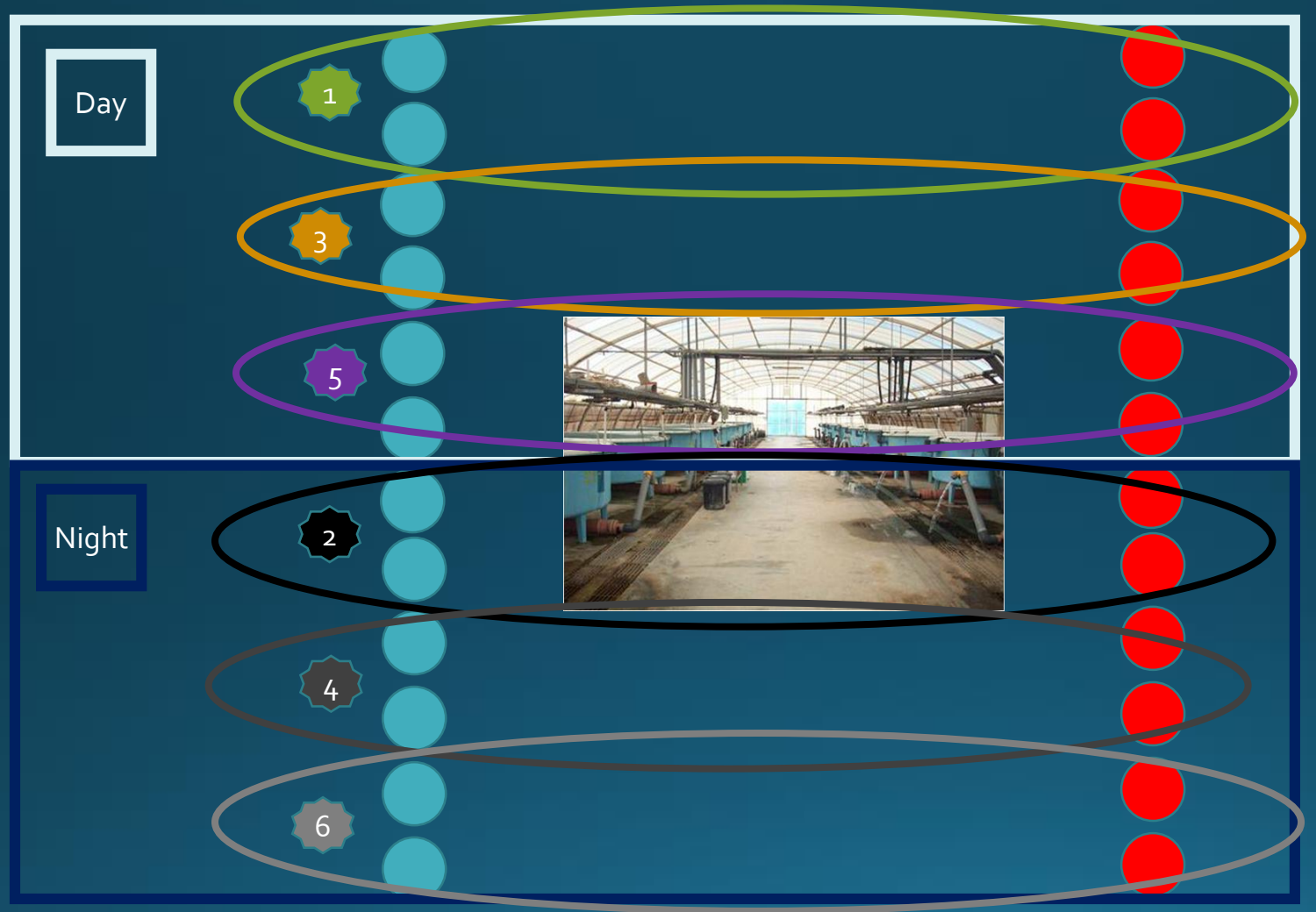
2. Percent of success of stocking between day and night

t = 15°C

t = 27°C

Day

Night



Stocking with three repetitions within one week

First year stocking data

Number of fish	size	Average weight	Time of stoking	Stock number	Date of stoking	CWT number
4,750	B (big)	5.7	M (morning)	1	15/05/2018	237606
4,680	S (small)	2.5	M	1	15/05/2018	210678
4,680	B	6.1	E (evening)	1	15/05/2018	237601
4,540	S	3.1	E	1	15/05/2018	210679
2,933	B	7.05	M	2	24/05/2018	237602
2,200	S	3.5	M	2	24/05/2018	210682
4,493	B	6.05	E	2	24/05/2018	237605
4,961	S	3.6	E	2	24/05/2018	210680
4,100	B	6.3	M	3	30/05/2018	237603
4,240	S	2.8	M	3	30/05/2018	210683
4,575	B	6.3	E	3	30/05/2018	237604
4,722	S	2.6	E	3	30/05/2018	633285
50,874						Total

Second year stocking data

Number of fish	size	Average weight (g)	Time of stoking	Stock number	Date of stoking	CWT number
3,080	B (big)	12.05	M (morning)	1	02/06/2019	237622
3,058	S (small)	6.32	M	1	02/06/2019	237615
3,054	B	12.12	E (evening)	1	02/06/2019	237620
3,075	S	6.10	E	1	02/06/2019	237616
3,051	B	11.31	M	2	11/06/2019	237624
3,050	S	5.60	M	2	11/06/2019	237614
3,053	B	15.61	E	2	11/06/2019	237621
3,070	S	8.65	E	2	11/06/2019	237617
2,835	B	13.61	M	3	18/06/2019	237623
3,065	S	5.51	M	3	18/06/2016	237613
3,059	B	16.50	E	3	18/06/2019	237619
3,068	S	7.23	E	3	18/06/2019	237618
36,518						Total
		13.53				Average weight B
		6.57				Average weight S

Future plans / dreams

To promote Stock Enhancement program in the Levantine sea

Creating international collaborations for programming a regional **responsible** stocking fogram

Declaration of protected marine reserves


Thank you
Questions?