Functional and metabolic evolution of fish

(on example of fatty acid content adaptation in populations of different species)

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Scheme of biological progress and biodiversity

(*after Severtsev, 1934*)

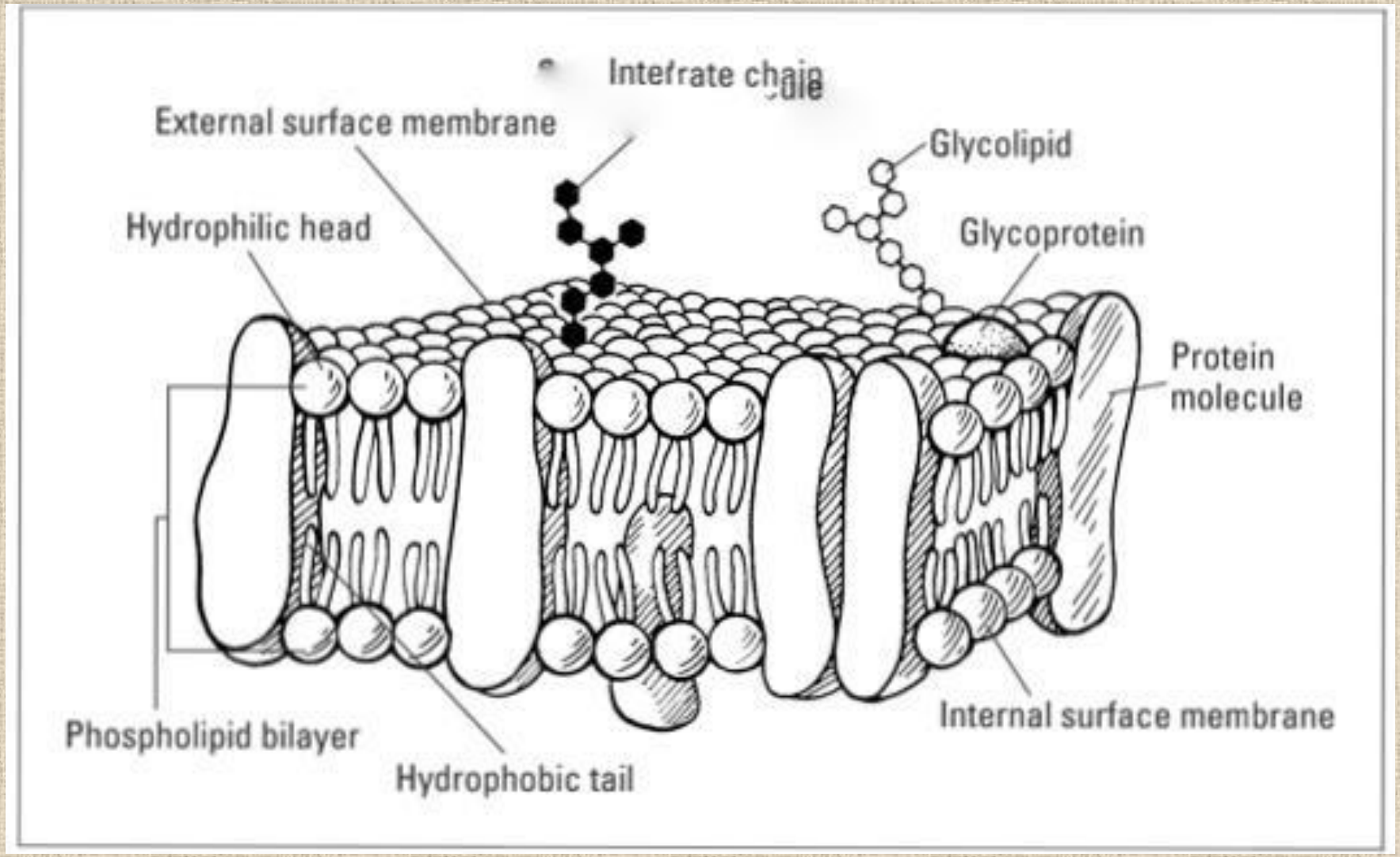
I	II
Expansion	**Specialization**
Development of enormous areas	**Occupation of narrow ecological niches**
High biomass and productivity	
High inter- and intra- species differentiation	**High inter- and intra- species differentiation**

Rate of oxygen consumption by different Black Sea fish, ml $g^{-1}h^{-1}$

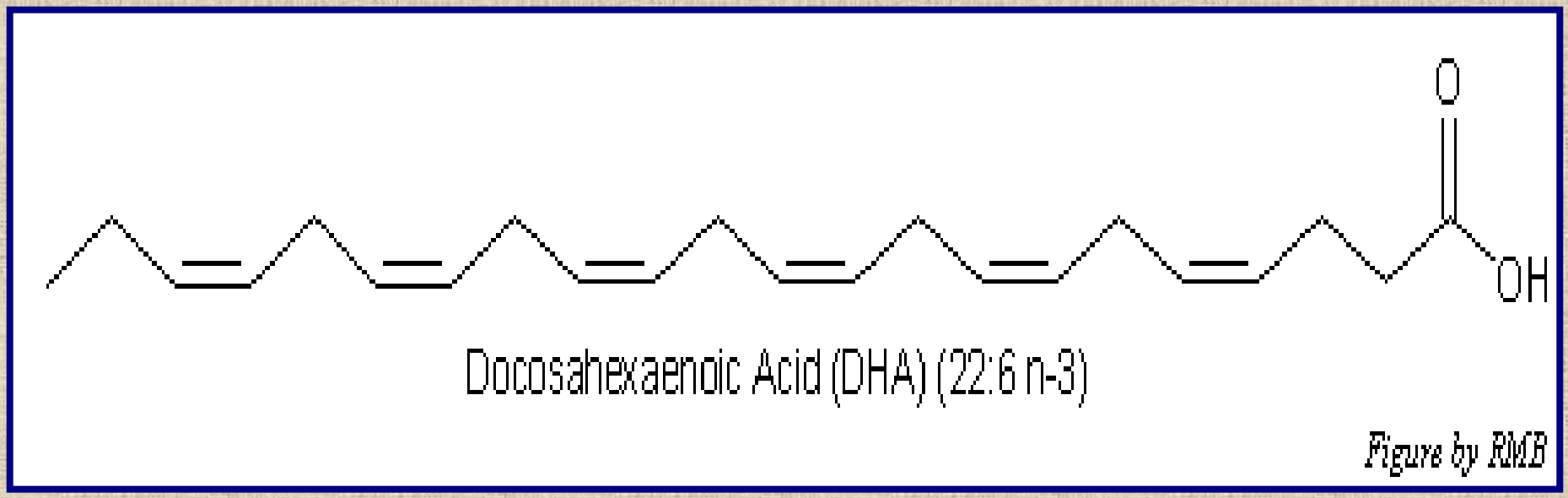
(*after Belokopytin, 1993; Shulman and Love, 1999*)

Species	Standard metabolism
Anchovy *Engraulis encrasicolus ponticus*	0.970
Horse-mackerel *Trachurus mediterraneus ponticus*	0.700
Mullet *Mugil cephalus*	0.572.
Pickerel *Spicara smaris*	0.572
Red mullet *Mullus barbatus*	0.247
Whiting *Merlangus merlangus euxinus*	0.276
Scorpion fish *Scorpaena porcus*	0.084

Membrane Structure

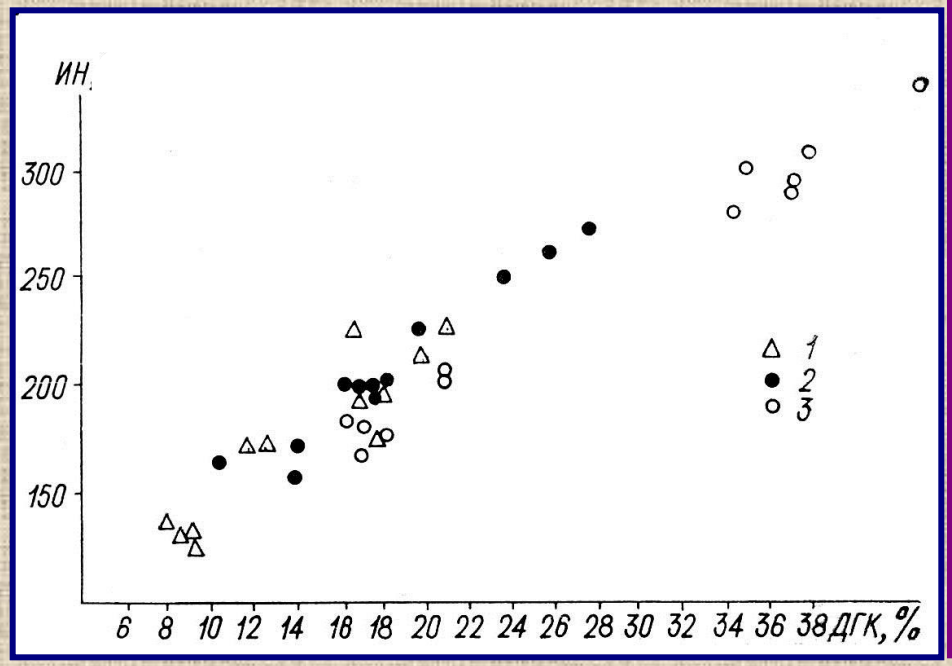


Chemical structure of docosahexaenoic acid, or DHA (22:6n-3)

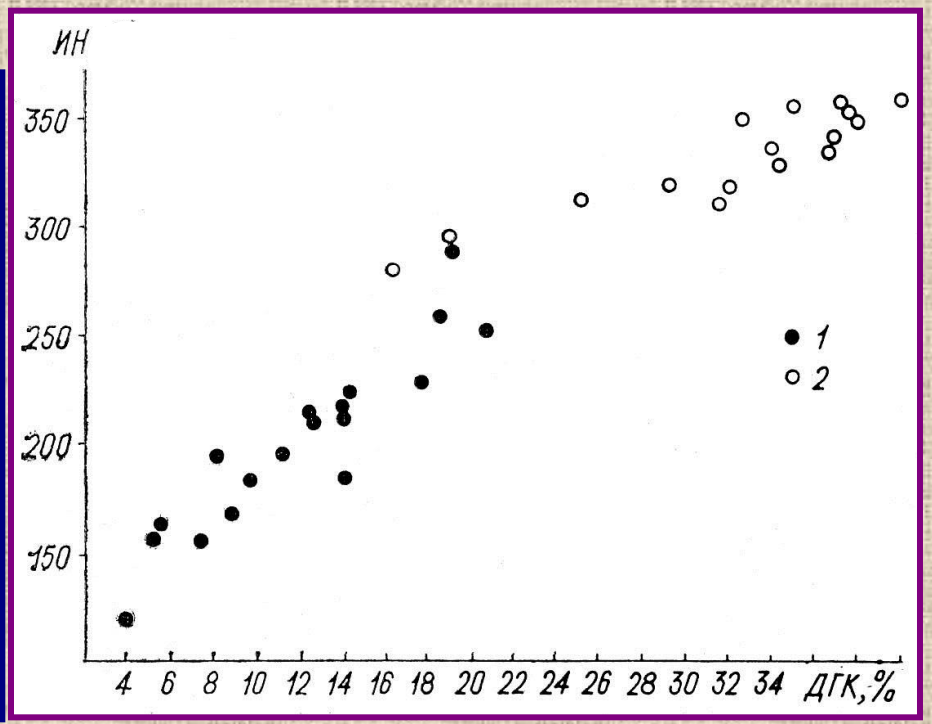


Unsaturation Index and 22:6n-3 content in fish
(Shulman, Yuneva, 1990)

a) the Black sea anchovy



b) pink salmon (white muscles)



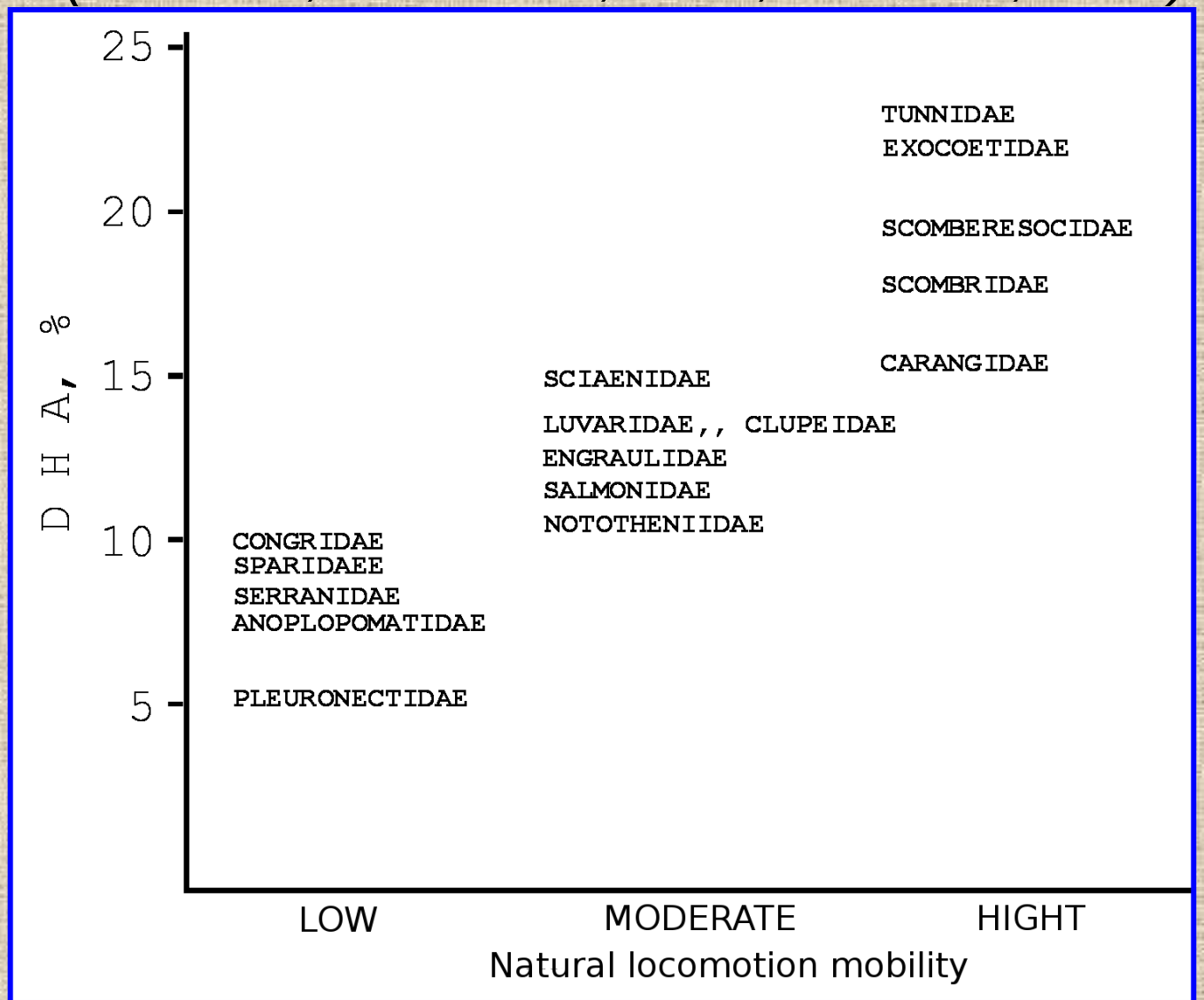
Seasonal variation in the principal fatty acids (%) in the muscle of capelin *Mallotus villosus*

(Henderson et al., 1984)

Fatty acid	January	August	January	August
14:0	4.8	5.9	3.8	7.6
16:0	22.1	25.1	19.3	23.0
16:1	8.5	8.3	6.9	7.8
18:0	1.8	1.2	1.4	1.1
18:1	26.0	28.0	20.8	22.4
18:2	1.4	1.8	1.4	1.7
18:4	1.4	4.6	1.5	4.2
20:1	2.3	1.3	4.1	4.4
22:5	13.8	10.8	16.8	10.7
22:1	2.0	1.0	3.8	4.4
22:6	11.3	6.7	15.4	8.3

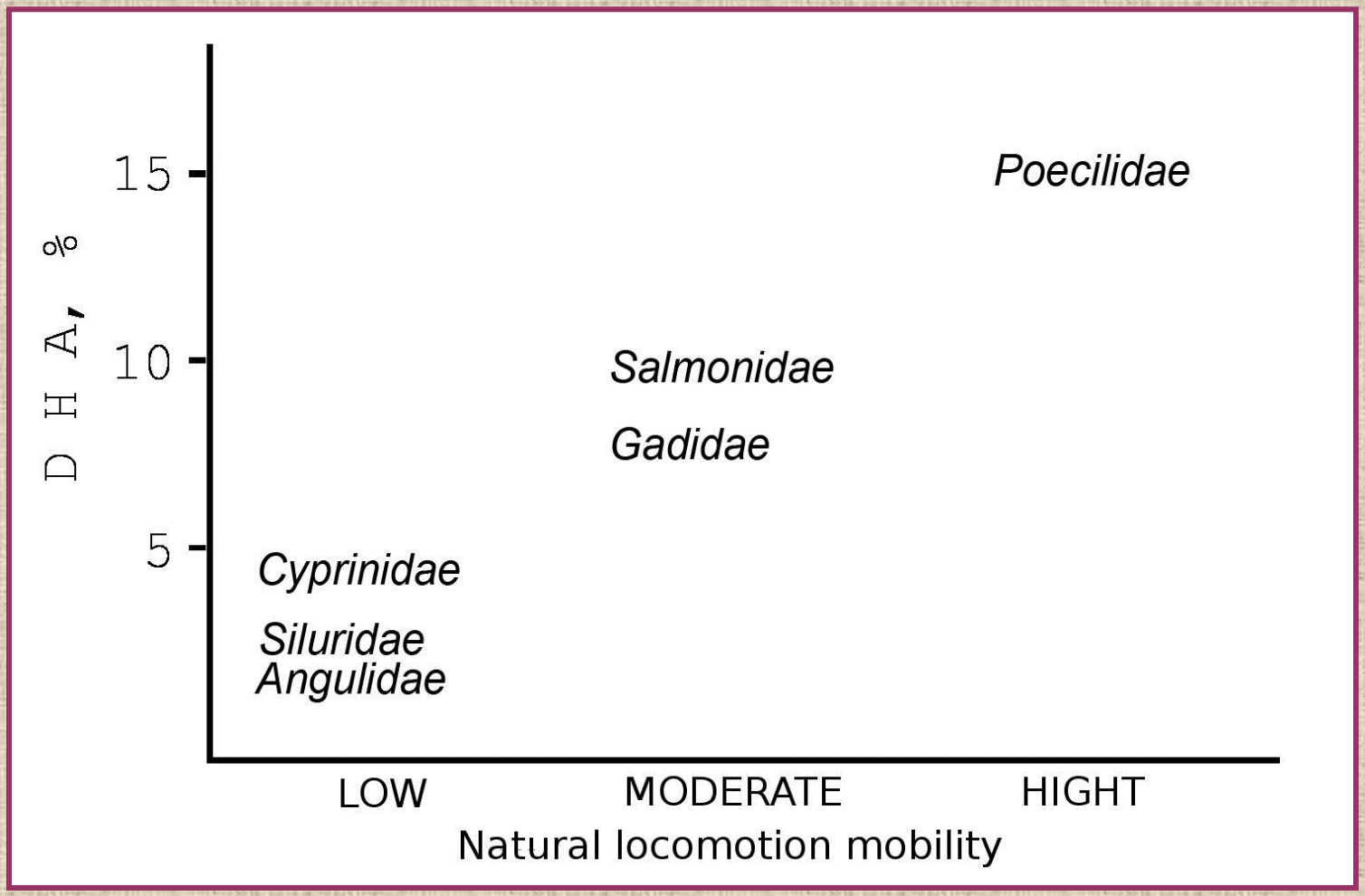
Relationship between large taxons of marine fishes and C22:6 n– 3 content in their lipids

(Shulman, Yakovleva, 1983; Shulman, 2014)



The same in freshwater fishes

(*Shulman, Yakovleva, 1983*)

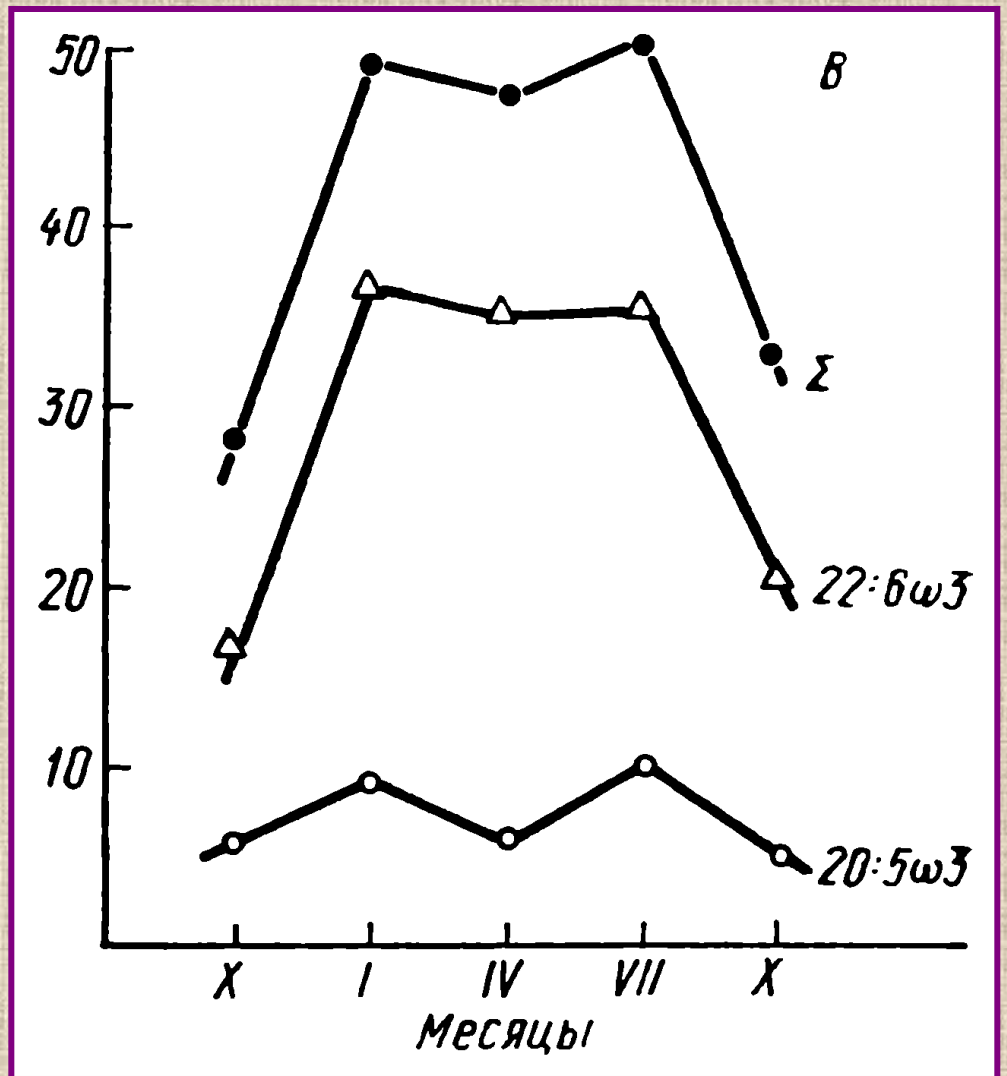


The same in marine invertabrates

Animal	Species	22:6ω3, %	Authors
Molluscs			
Squids	*Sthenoteuthis pteropus*	44.0	Yuneva et al., 1994
	Illex illecebrosus	40.7	Jangaard and Ackman, 1965
Cuttlefish	*Heteroteuthis dispar*	32.0	Culkin and Morris, 1970
Octopus	*Eledonela pygmaea*	22.8	Culkin and Morris, 1970
Pecten	*Pecten maximus*	8.4	Ackman, 1982
Mussel	*Mytilus edulis*	3.2	Ackman, 1982
Oyster	*Ostrea edulis*	2.3	Ackman, 1982
Crustacean			
Copepoda	*Calanus euxinus*	39.8	Yuneva et al., 1998
Euphausida	*Stylocheiron abbreviatum*	29.2	Yuneva et al., 1992
Fishes			
Anchovy	*Engraulis encrasicolus*	34.6	Yuneva, 1990
Horse mackerel	*Trachurus mediterraneus ponticus*	40.0	Yuneva et al., 1991

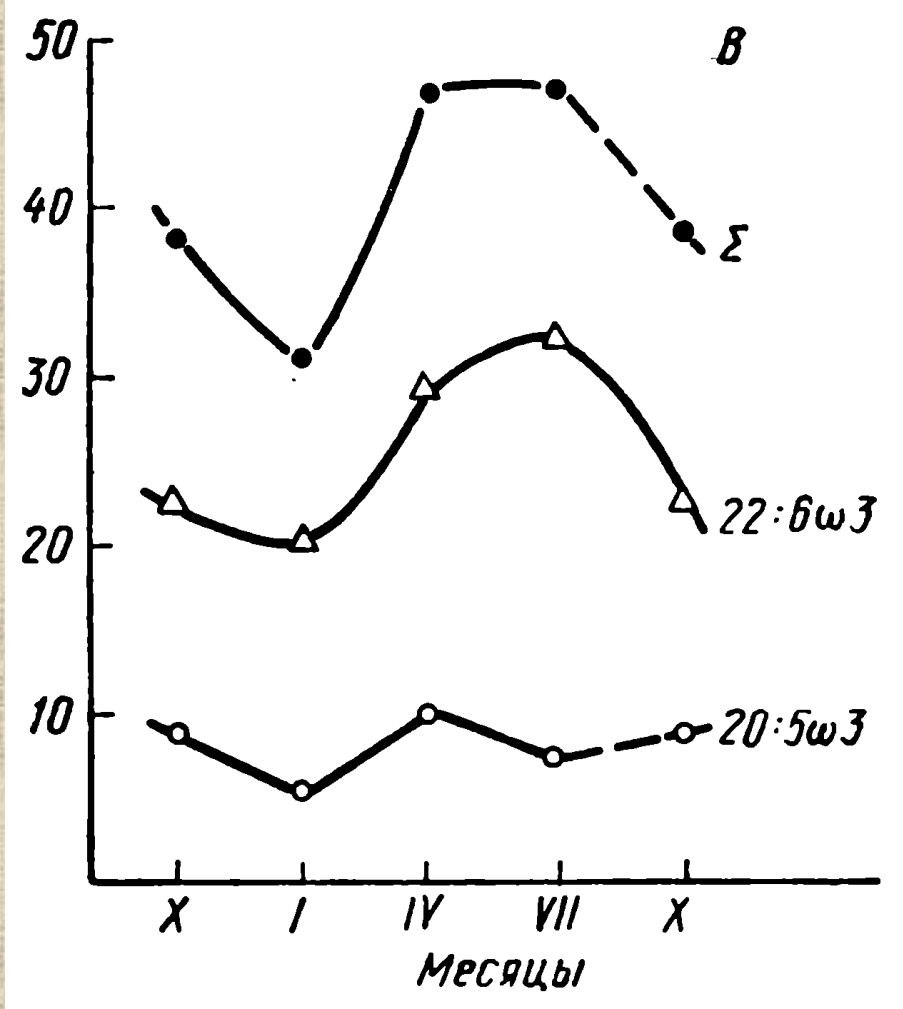
Dynamics of DNA, EPA and total polyunsaturated fatty acids (∑PUFA) in phospholipids of the Black sea anchovy during annual cycle

(Yuneva et al., 1990)



Dynamics of DNA, EPA and total polyunsaturated fatty acids (∑PUFA) in phospholipids of the Black sea sprat during annual cycle

(Yuneva et al., 1990)



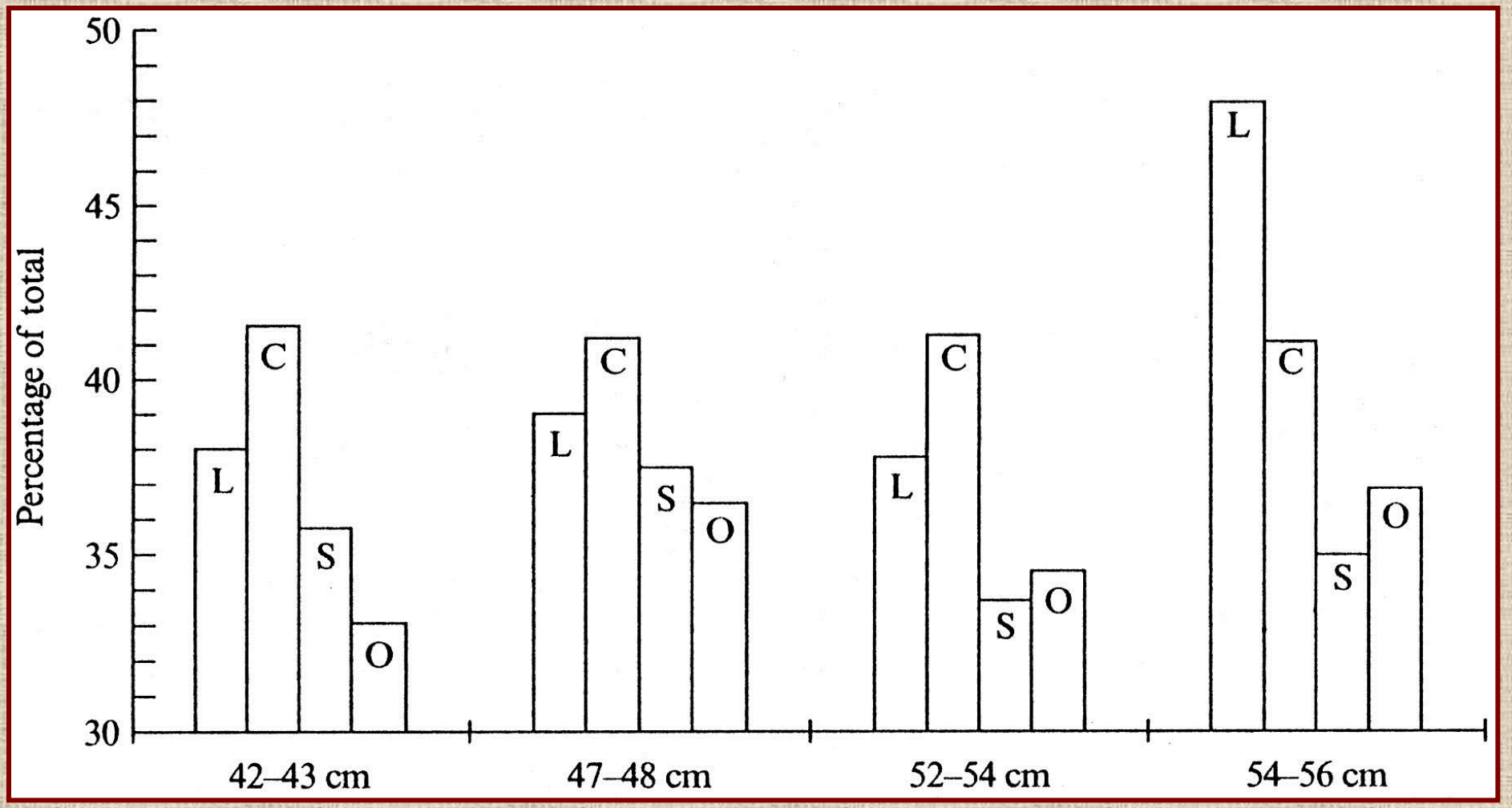
Iodine value (a measure of unsaturation) in the liver lipids of different species of goby from the Sea of Azov

(Shulman and Love, 1999; Shulman, 2014)

Species	males	females
Neogobius syrman	**81.7**	**80.7**
Neogobius melanostomus	**128.8**	**113.7**
Neogobius fluviatilis	**153.7**	**145.0**
Neogobius rattan	**160.0**	**--**
Mesogobius batrachocephalus	**160.0**	**169.0**

Spawning relationships in *Oncorhinchus gorbuscha*

(Yuneva et al., 1987)



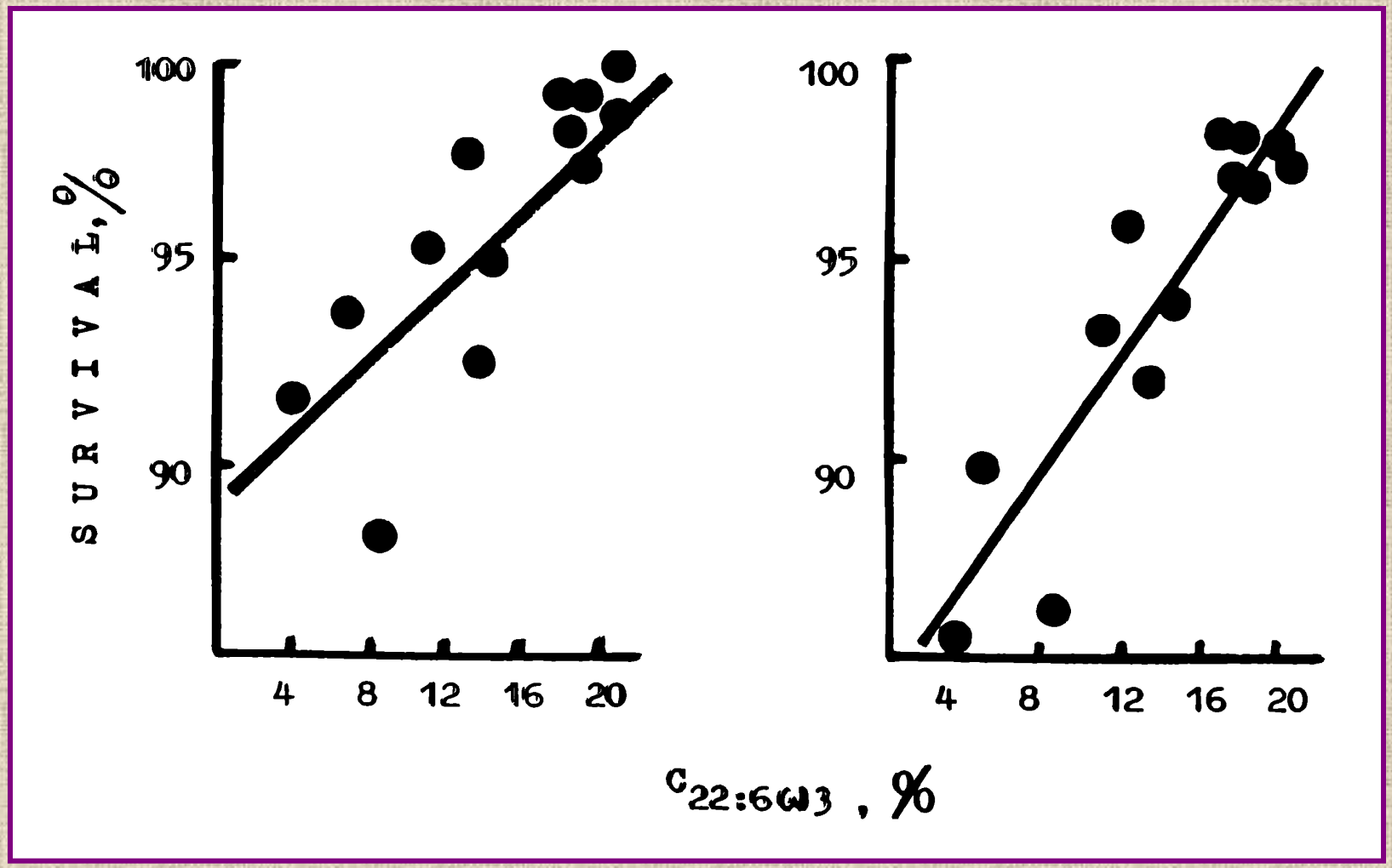
Docosohexaenoic acid (DHA) content of the eye lipids of saury-pike

(*Shulman, Love, 1999, the data of T.V.Yuneva*)

	Rate of photoreaction			
	I	**II**	**III**	**IV**
DHA in phospholipids (%)	38.5	37.6	43.5	45.9
DHA in triacyl-glycerols (%)	6.3	6.2	15.1	15.1

Relationship between (a) egg and (b) larval survival and 22:6 n-3 content in *Oncorhychus gorbuscha famales*

(Yuneva et al., 1990)



DHA (C22:6 n- 3) content in phospholipids of two Anchovy subspecies in feeding period, November--December

(Yuneva et al., 2011)

Years	Black Sea anchovy		Azov Sea anchovy	
	mg/100 g wet tissue	% of total fatty acids	mg/100 g wet tissue	% of total fatty acids
2005	**234**	**13.2 ± 1.6**	**-**	**-**
2006	**188**	**11.3 ± 2.3**	**161**	**7.5 ± 1.7**
2007	**269**	**7.9 ± 0.5**	**-**	**-**
2008	**238**	**9.7 ± 0.4**	**151**	**6.8 ± 1.3**

The races (subspecies) of anchovy:

Engraulis encrasicolis maeoticus; E.e. ponticus and *E.e.mediterraneus.*
*(*protein, fat, total energy equivalent)
(*Shulman, 1974*)