Journée des doctorants
CARRTEL
15 juin 2017

Sensibilité de la structure et du fonctionnement du réseau trophique aux fortes variations d'abondances de poissons

Marine Lemaire[1], Jean Guillard[1], Jérémy Lobry[2], Orlane Anneville[1]
[1] CARRTEL, INRA, Université Savoie Mont Blanc, 75 avenue de Corzent, 74200 Thonon-les-Bains
[2] IRSTEA, UR EABX Aquatic Ecosystem and Global Changes, 50 avenue de Verdun-Gazinet, 33610, Cestas

CONTEXTUAL BACKGROUND

LIMNOLOGY AND OCEANOGRAPHY
Letters

ASLO
Open Access

Limnology and Oceanography Letters 00, 2017, 00–00

doi: 10.1002/lol2.10037

LETTER

Extreme events in lake ecosystem time series

Ryan D. Batt [1,a]* *Stephen R. Carpenter,*[1] *Anthony R. Ives*[2]
[1]Center for Limnology, University of Wisconsin – Madison, Madison, Wisconsin; [2]Department of Zoology, University of Wisconsin – Madison, Madison, Wisconsin

Numerous studies on environmental extreme events

≠

Few studies on biological extreme events

➔ Natural fish demographic variability

CONTEXTUAL BACKGROUND

LIMNOLOGY AND OCEANOGRAPHY
Letters

ASLO
Open Access

Limnology and Oceanography Letters 00, 2017, 00–00

doi: 10.1002/lol2.10037

LETTER

Extreme events in lake ecosystem time series

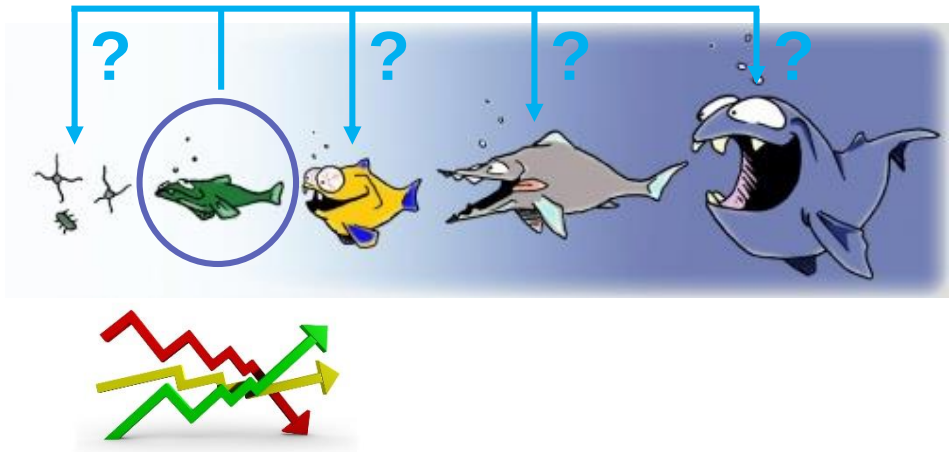
Ryan D. Batt [1,a]* *Stephen R. Carpenter,* [1] *Anthony R. Ives* [2]
[1]Center for Limnology, University of Wisconsin – Madison, Madison, Wisconsin; [2]Department of Zoology, University of Wisconsin – Madison, Madison, Wisconsin

Numerous studies on environmental extreme events

≠

Few studies on biological extreme events

➔ Natural fish demographic variability



CONTEXTUAL BACKGROUND

LIMNOLOGY AND OCEANOGRAPHY
Letters
ASLO
Open Access
Limnology and Oceanography Letters 00, 2017, 00–00

doi: 10.1002/lol2.10037

LETTER

Extreme events in lake ecosystem time series

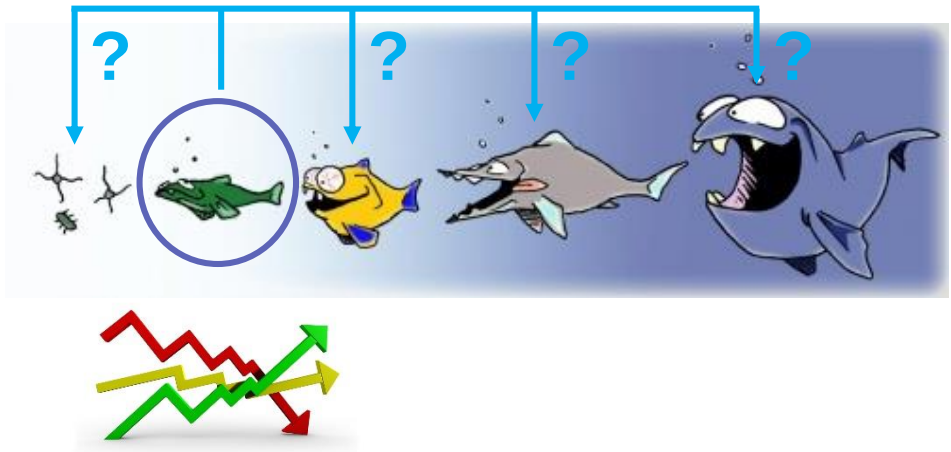
Ryan D. Batt [1,a]* *Stephen R. Carpenter,* [1] *Anthony R. Ives* [2]
[1]Center for Limnology, University of Wisconsin – Madison, Madison, Wisconsin; [2]Department of Zoology, University of Wisconsin – Madison, Madison, Wisconsin

Numerous studies on environmental extreme events

≠

Few studies on biological extreme events

➔ Natural fish demographic variability

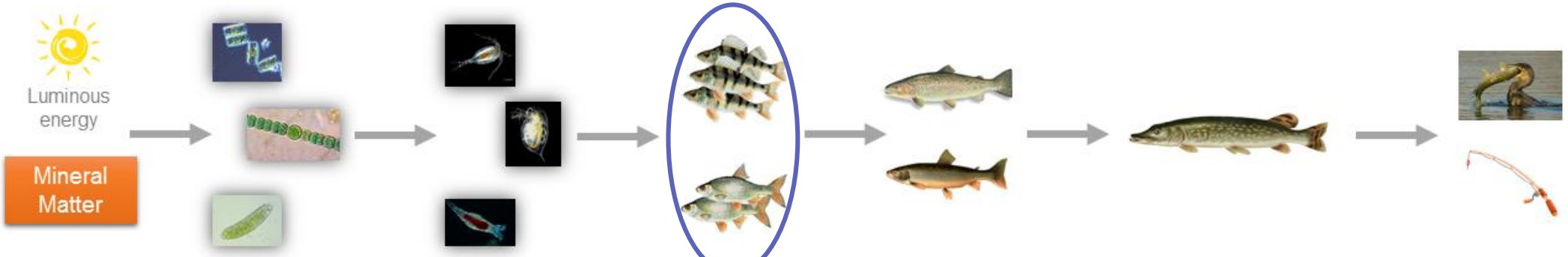


DO THE **FLUCTUATIONS** IN THE ABUNDANCE OF **INTERMEDIATE TROPHIC GROUP** IMPACT THE **STRUCTURE** AND **FUNCTIONING** OF AQUATIC **FOOD WEB**?

CONTEXTUAL BACKGROUND: Lake Annecy

➔ Peri-alpine lake
➔ Stable oligotrophic status for decades

CONTEXTUAL BACKGROUND: Lake Annecy

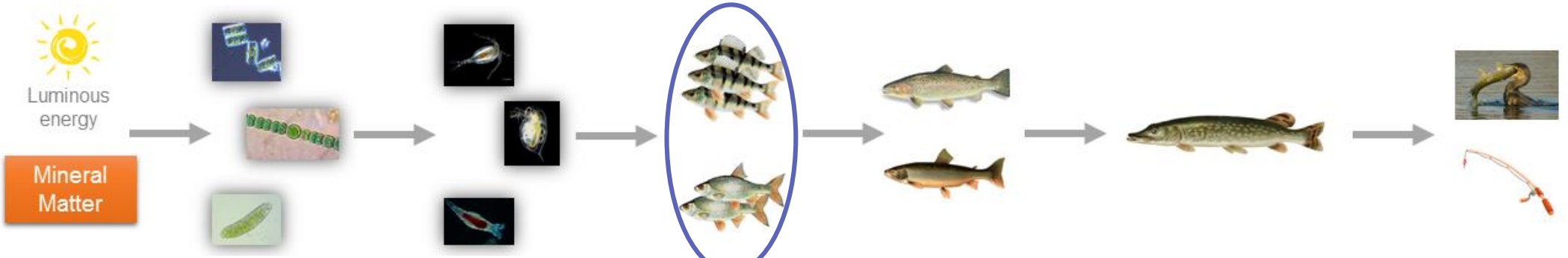


Vegetal plankton = ***Primary producer***

Animal plankton = ***Primary consumer***

Secondary, tertiary… consumers

CONTEXTUAL BACKGROUND: Lake Annecy

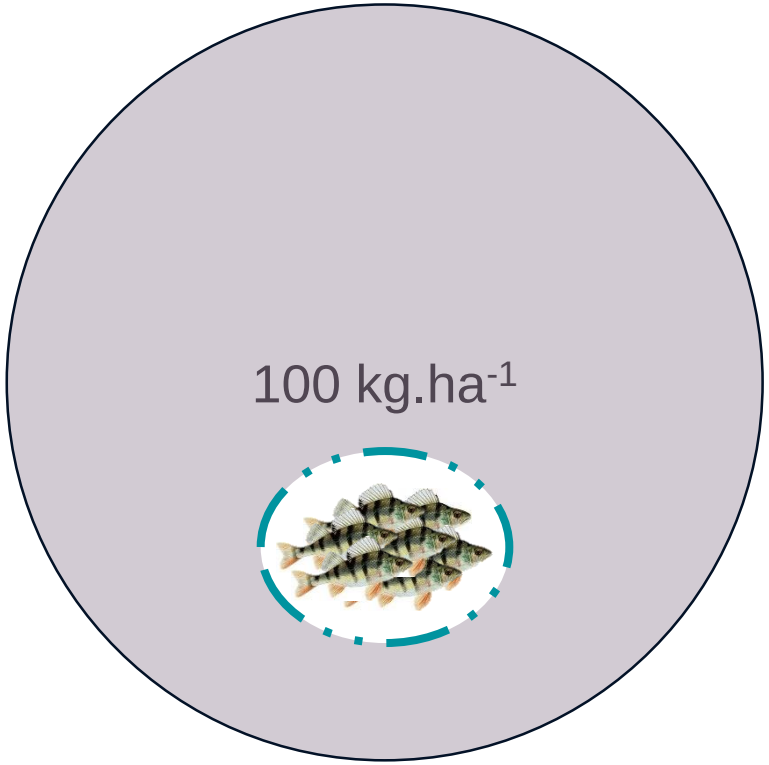


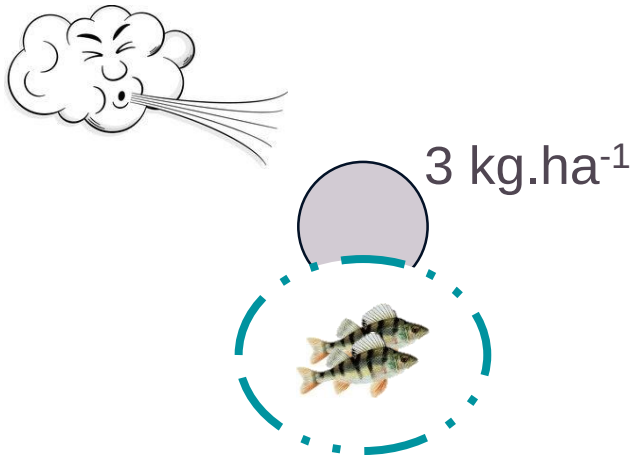
Vegetal plankton = ***Primary producer***

Animal plankton = ***Primary consumer***

Secondary, tertiary… consumers

Young of the Year (YOY) perch





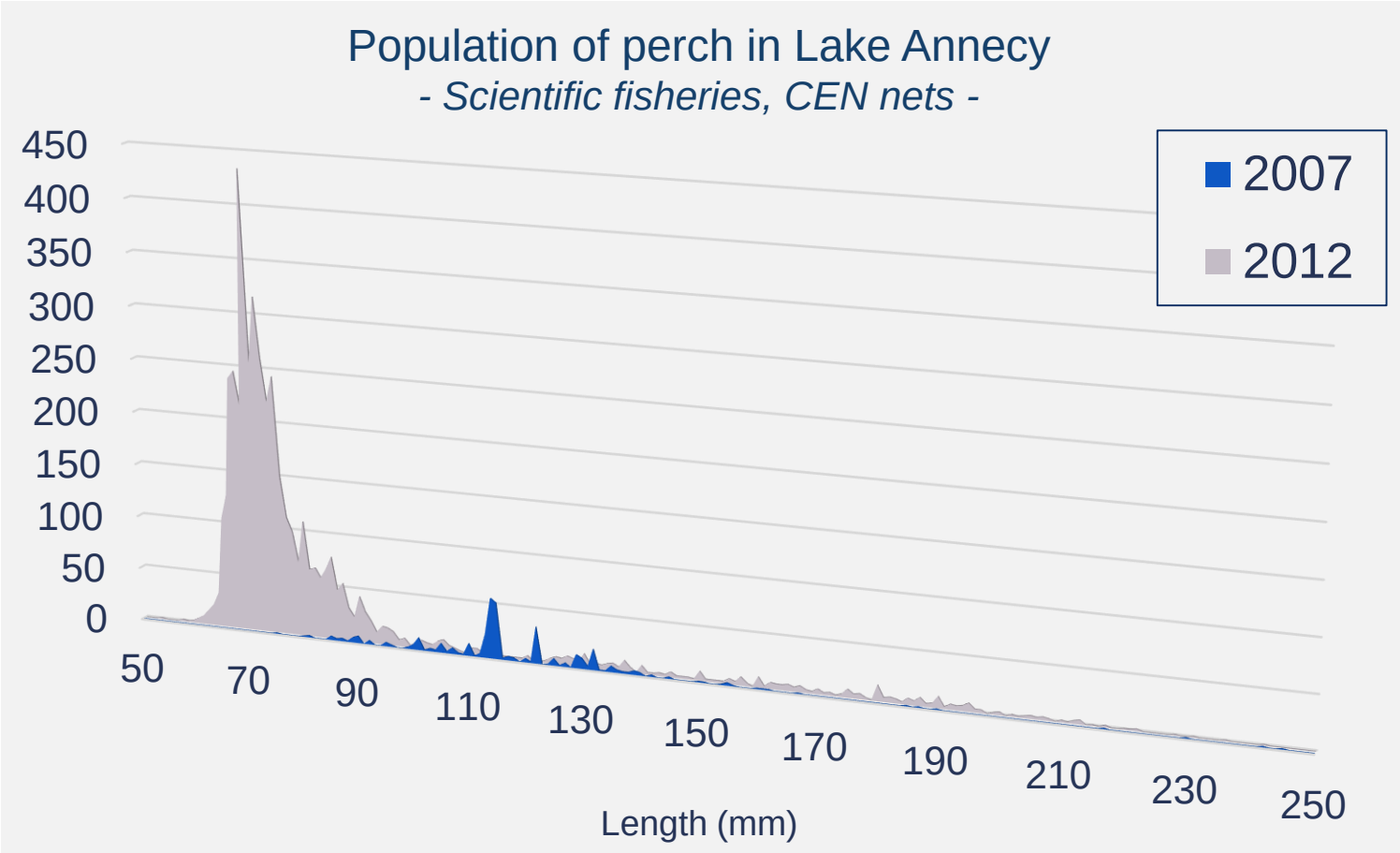
IMPACTS OF FLUCTUATION IN ABUNDANCE OF **YOY PERCH** ON **LAKE ANNECY** FOOD WEB STRUCTURE AND FUNCTIONING?

1. Study of two existing years contrasted in terms of YOY perch biomass

2. Level of YOY perch biomass the system can receive

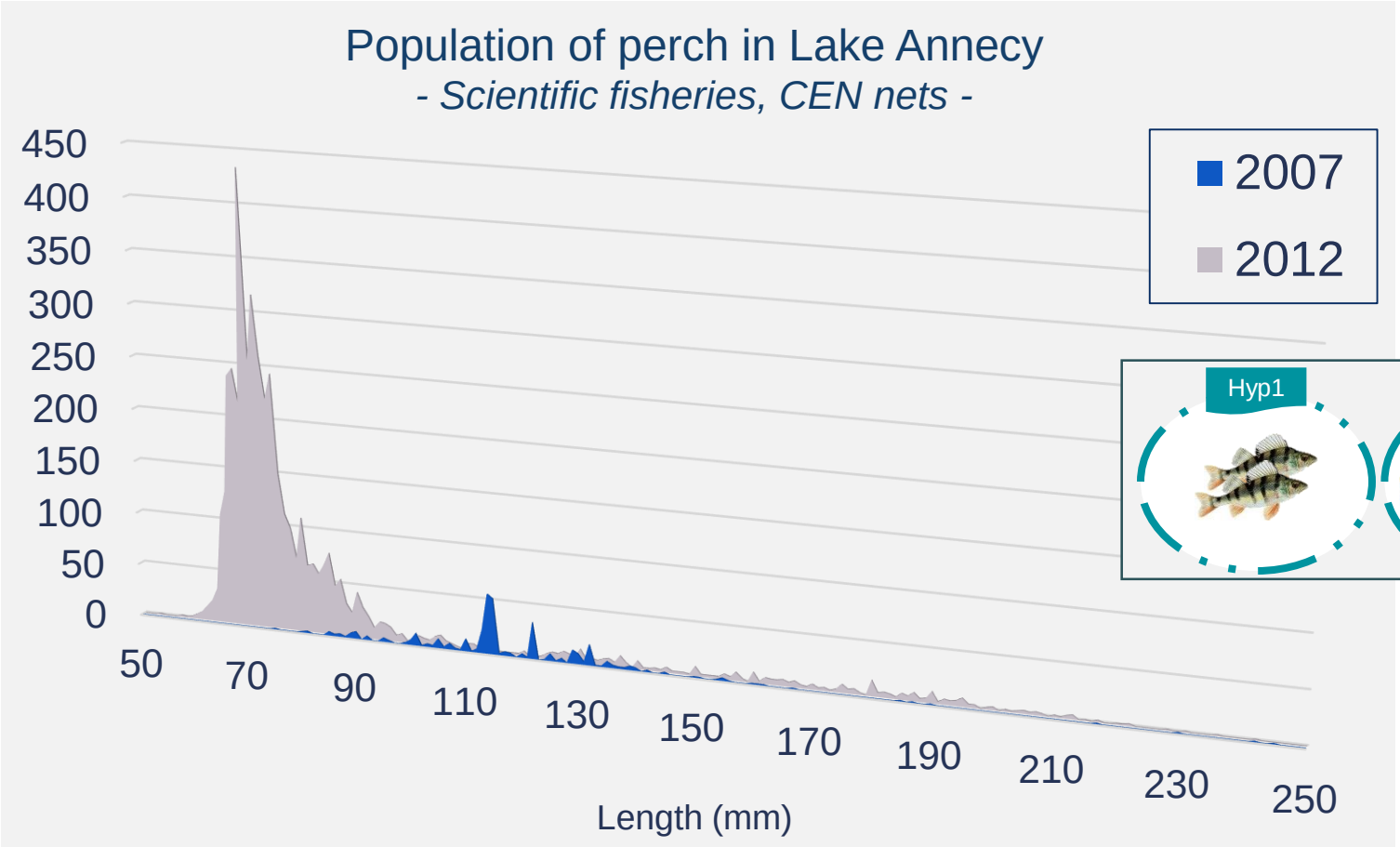
IMPACTS OF FLUCTUATION IN ABUNDANCE OF **YOY PERCH** ON **LAKE ANNECY** FOOD WEB STRUCTURE AND FUNCTIONING?

1. Study of two existing years contrasted in terms of YOY perch biomass



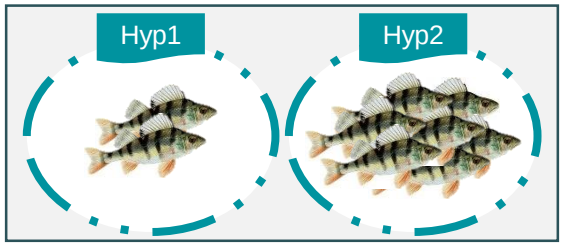
IMPACTS OF FLUCTUATION IN ABUNDANCE OF **YOY PERCH** ON **LAKE ANNECY** FOOD WEB STRUCTURE AND FUNCTIONING?

1. Study of two existing years contrasted in terms of YOY perch biomass



IMPACTS OF FLUCTUATION IN ABUNDANCE OF **YOY PERCH** ON **LAKE ANNECY** FOOD WEB STRUCTURE AND FUNCTIONING?

1. Study of two existing years contrasted in terms of YOY perch biomass

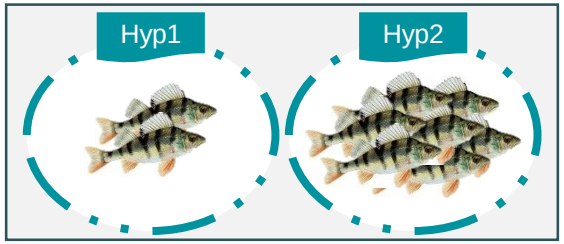


2. Level of YOY perch biomass the system can receive

Bmin = ?
Bmax = ?

IMPACTS OF FLUCTUATION IN ABUNDANCE OF **YOY PERCH** ON **LAKE ANNECY** FOOD WEB STRUCTURE AND FUNCTIONING?

1. Study of two existing years contrasted in terms of YOY perch biomass



2. Level of YOY perch biomass the system can receive

Bmin = ?
Bmax = ?

Ecopath model

MATERIAL & METHOD: Ecopath model

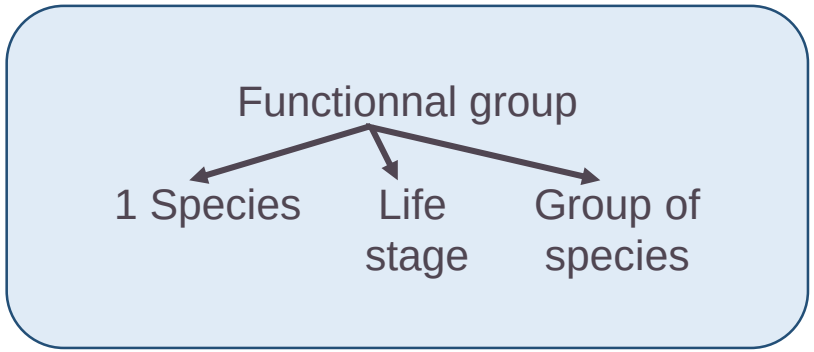
Ecopath ➔ study of the structure and functioning of food webs

- Fundamental principle: **Mass-balanced** model

MATERIAL & METHOD: Ecopath model

Ecopath ➔ study of the structure and functioning of food webs

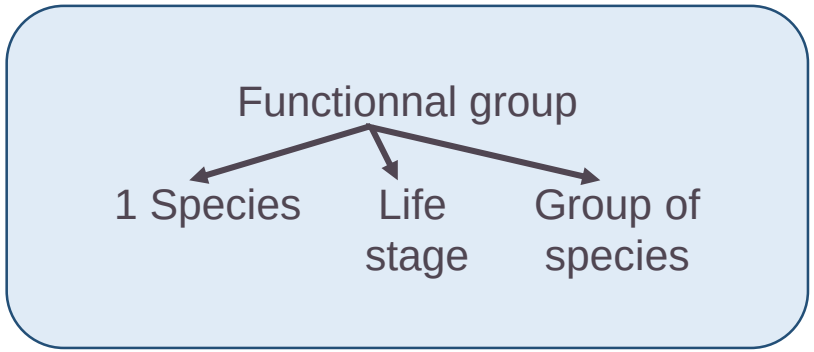
Fundamental principle: **Mass-balanced** model



MATERIAL & METHOD: Ecopath model

Ecopath ➔ study of the structure and functioning of food webs

- Fundamental principle: **Mass-balanced** model



- Governed by two equations

1. Equation of production

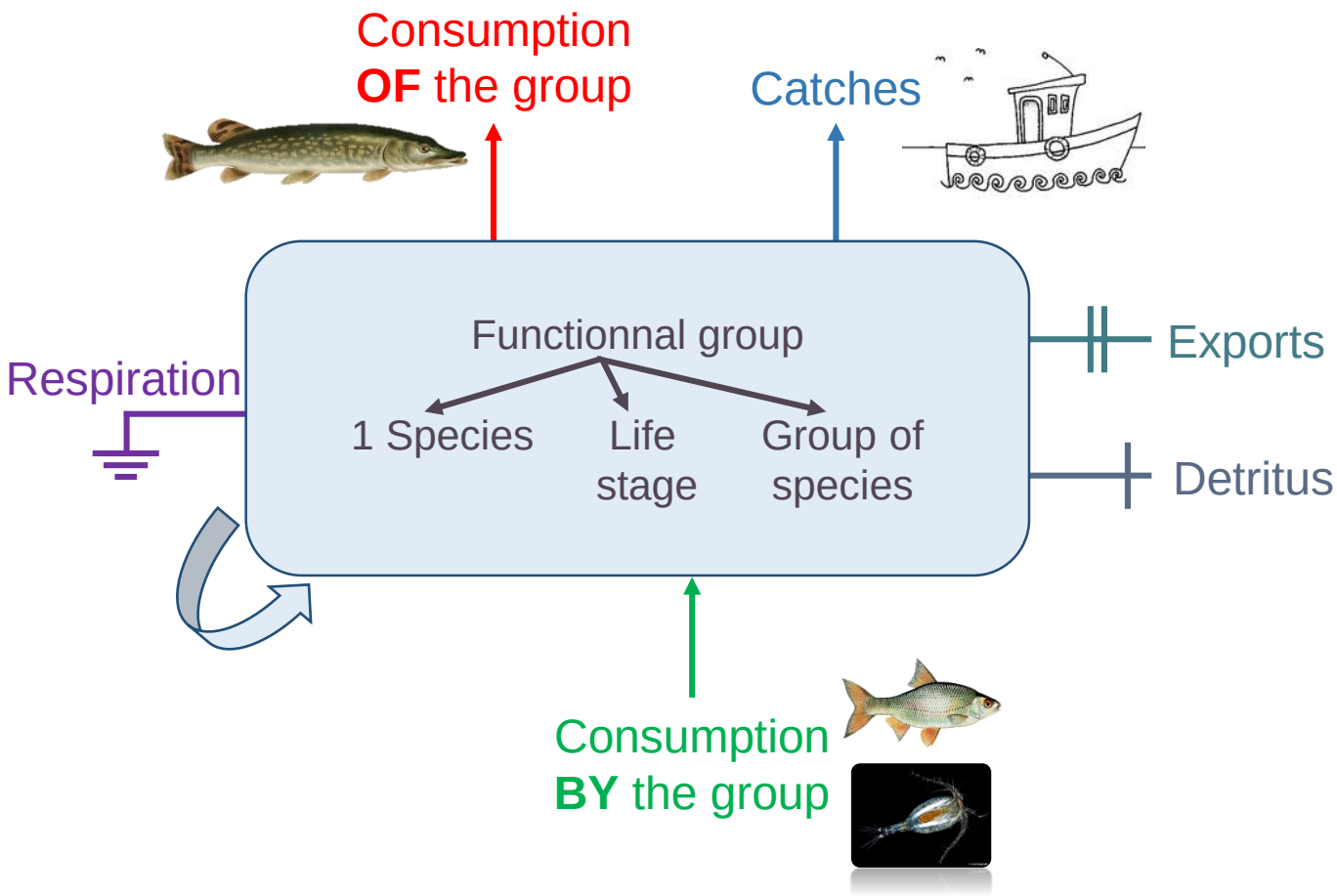
Production = Fishery
+ Predation
+ other Mortality
+ Biomass accumulation
+ net Migration

2. Equation of consumption

Consumption = Production
+ Respiration
+ Unassimilated food

Ecopath ➔ study of the structure and functioning of food webs

Fundamental principle: **Mass-balanced** model



Governed by two equations

1. Equation of production

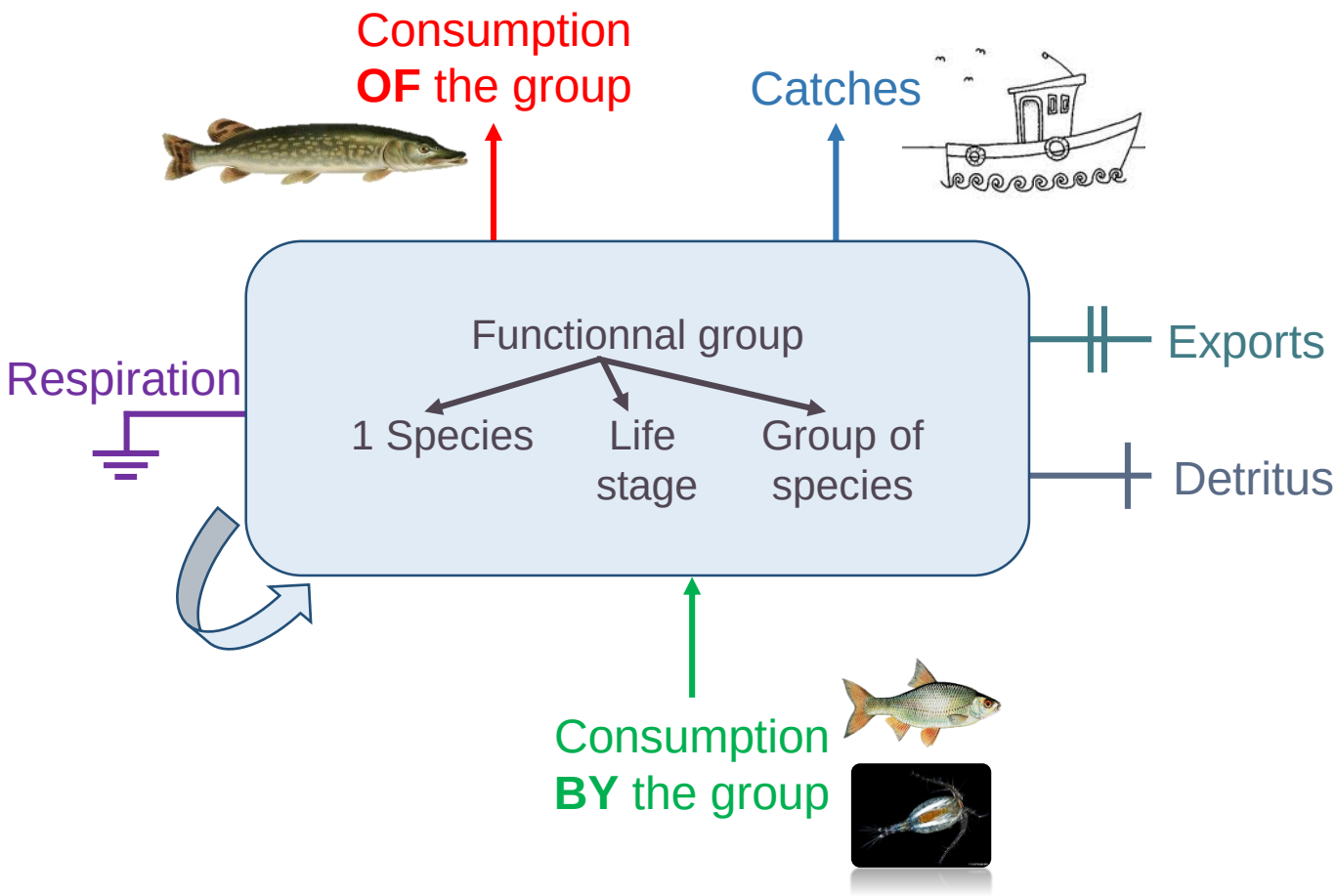
Production = Fishery
+ Predation
+ other Mortality
+ Biomass accumulation
+ net Migration

2. Equation of consumption

Consumption = Production
+ Respiration
+ Unassimilated food

Ecopath ➔ study of the structure and functioning of food webs

Fundamental principle: **Mass-balanced** model



Governed by two equations

1. Equation of production

Production = Fishery
+ Predation
+ other Mortality
+ Biomass accumulation
+ net Migration

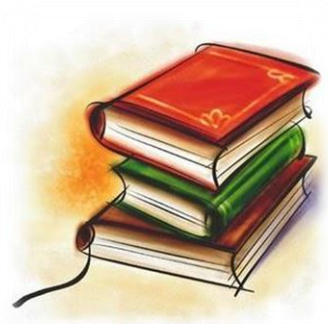
2. Equation of consumption

Consumption = Production
+ Respiration
+ Unassimilated food

Potential representations of the ecosystem

MATERIAL & METHOD: Ecopath model - DATA

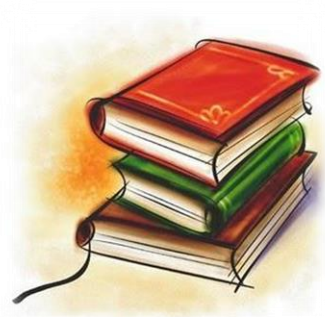
Ecopath ➔ study of the structure and functioning of food webs



Observatoire des LAcs alpins

MATERIAL & METHOD: Ecopath model - DATA

Ecopath ➔ study of the structure and functioning of food webs



Observatoire des LAcs alpins

Divide the ecosystem in 19 functional groups

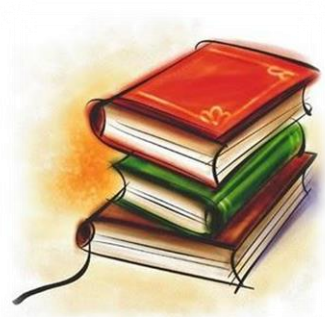
19 groups: 14 fish groups + zoobenthos + zooplankton + phytoplankton + macrophytes + detritus

1	Pike
2	Burbot
3	Arctic charr + 26
4	Arctic charr - 26
5	Trout
6	Tench
7	Perch
8	Perch YOY
9	Whitefish + 37
10	Whitefish - 37

11	Bullhead
12	Blenny
13	Roach
14	Cyprinids
15	Zoobenthos
16	Zooplankton
17	Phytoplankton
18	Macrophytes
19	Detritus

MATERIAL & METHOD: Ecopath model - DATA

Ecopath ➔ study of the structure and functioning of food webs



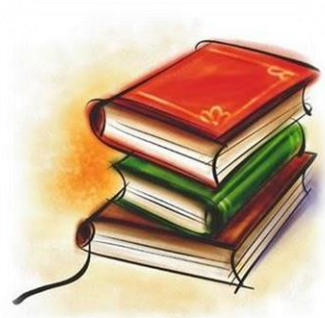
- Divide the ecosystem in 19 functional groups

  19 groups: 14 fish groups + zoobenthos + zooplankton + phytoplankton + macrophytes + detritus

- Compile the data required

MATERIAL & METHOD: Ecopath model - DATA

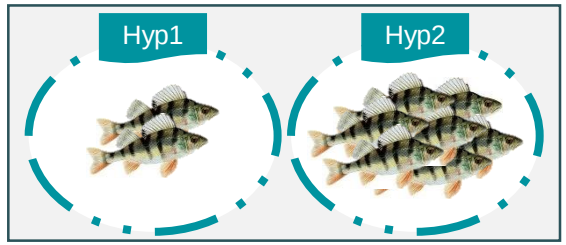
Ecopath ➔ study of the structure and functioning of food webs



- Divide the ecosystem in 19 functional groups

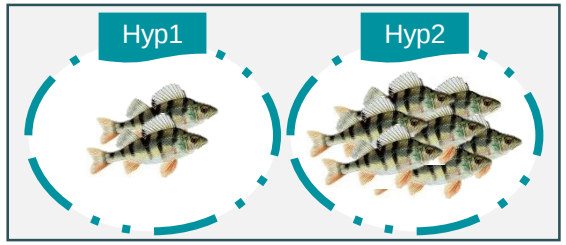
  19 groups: 14 fish groups + zoobenthos + zooplankton + phytoplankton + macrophytes + detritus

- Compile the data required

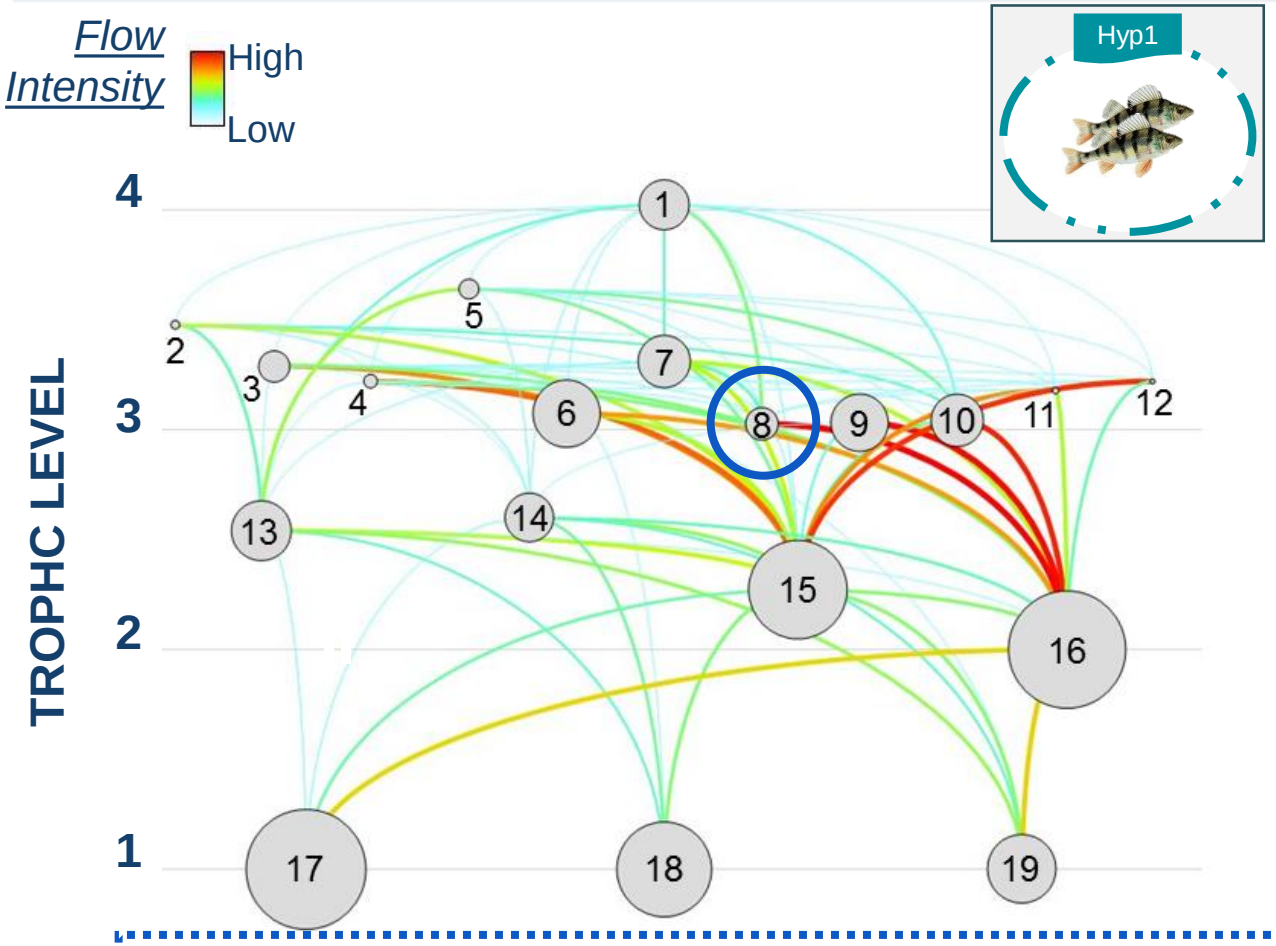


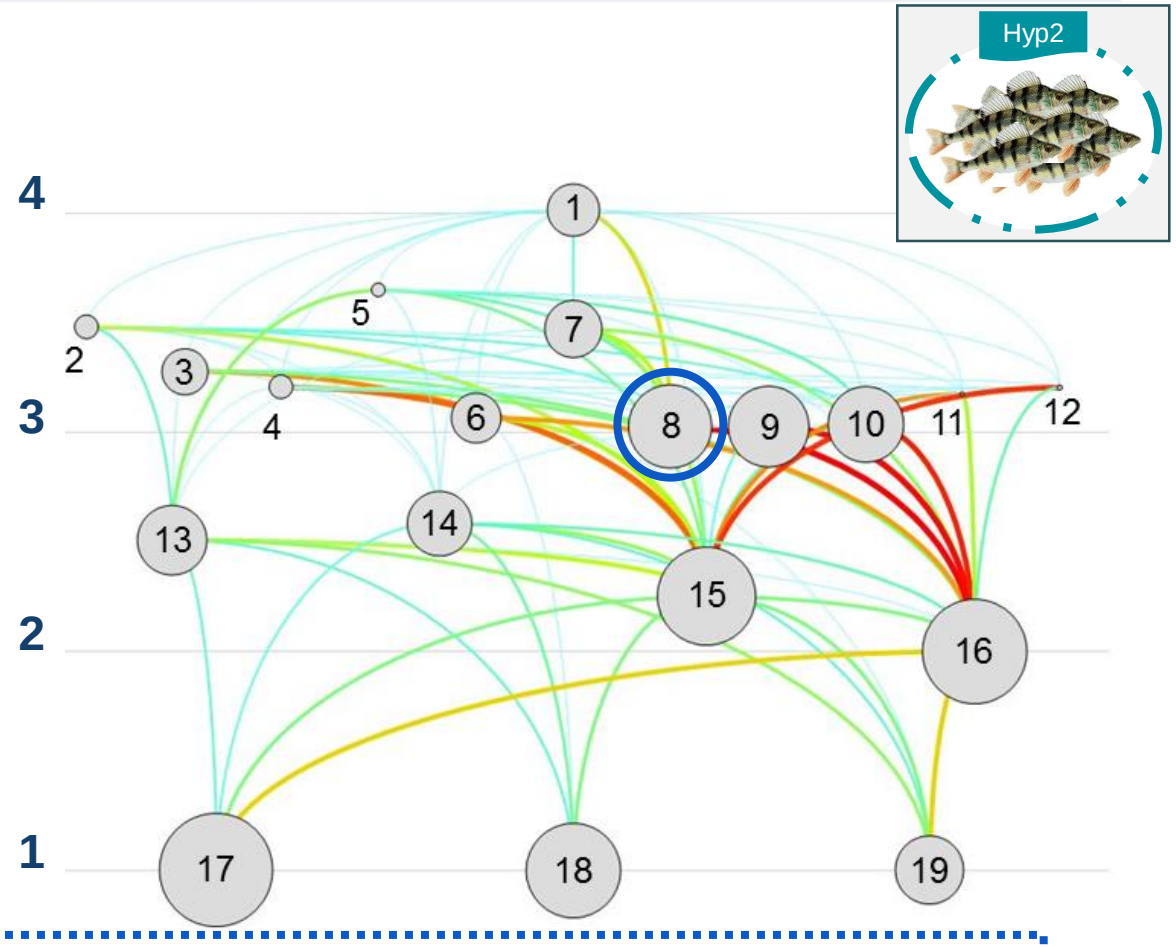
➔ 2 models

I. GENERAL STRUCTURE AND FUNCTIONING OF LAKE ANNECY FOOD WEB WITH LOW AND HIGH YOY PERCH BIOMASS



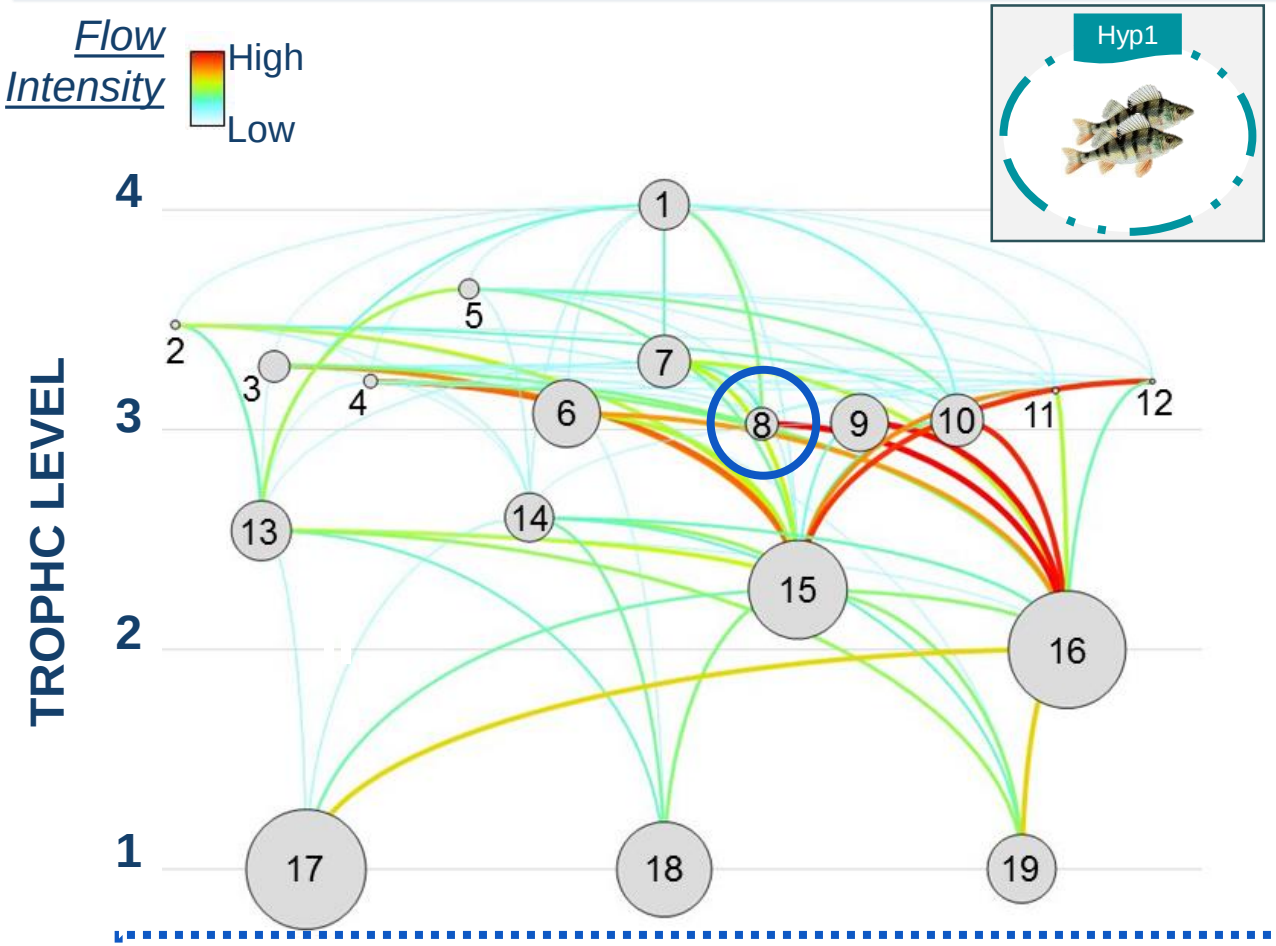
STRUCTURE AND FUNCTIONING OF LAKE ANNECY FOOD WEB

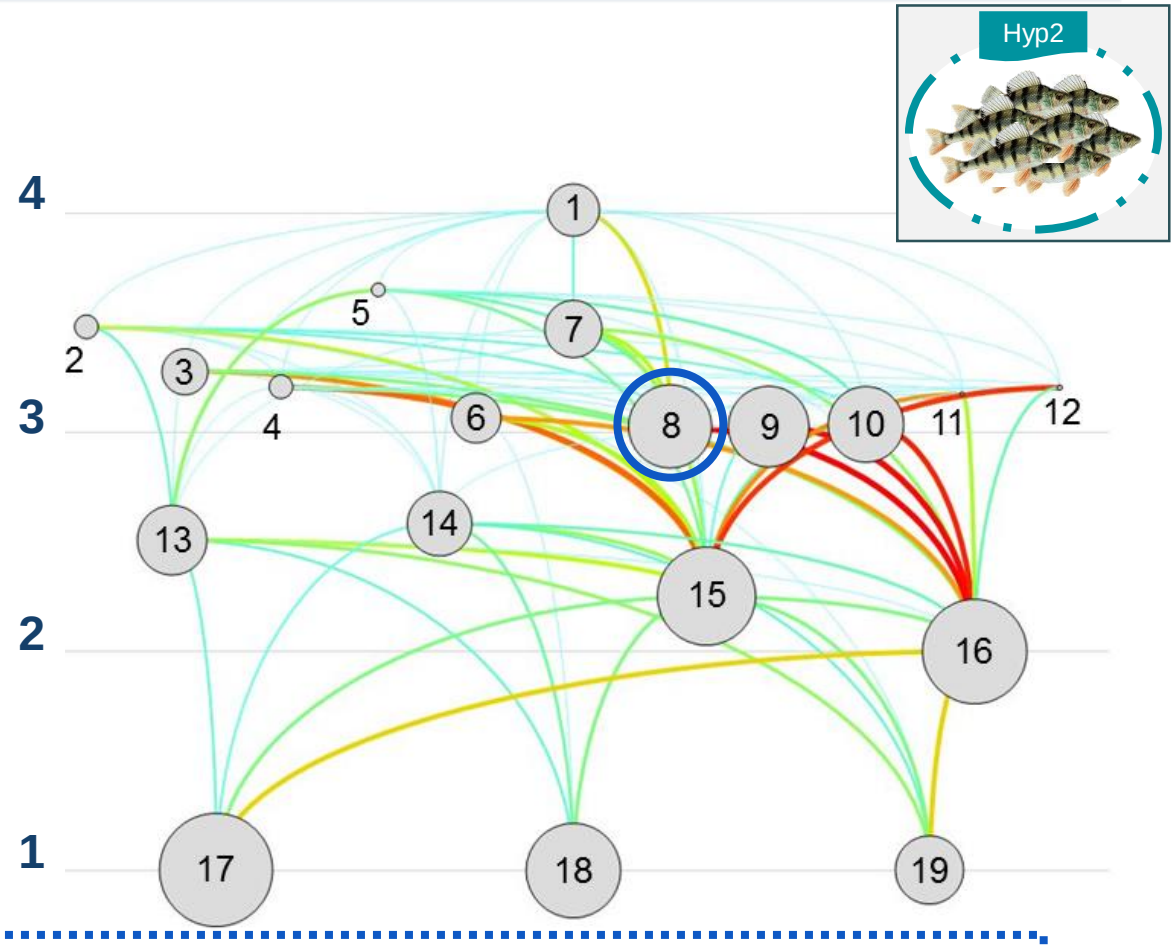




1. *Pike*
2. *Burbot*
3. *Arctic charr + 26*
4. *Arctic charr – 26*
5. *Trout*
6. *Tench*
7. *Perch*
8. *Perch YOY*
9. *Whitefish + 37*
10. *Whitefish - 37*
11. *Bullhead*
12. *Blenny*
13. *Roach*
14. *Cyprinids*
15. *Zoobenthos*
16. *Zooplankton*
17. *Phytoplankton*
18. *Macrophytes*
19. *Detritus*

STRUCTURE AND FUNCTIONING OF LAKE ANNECY FOOD WEB





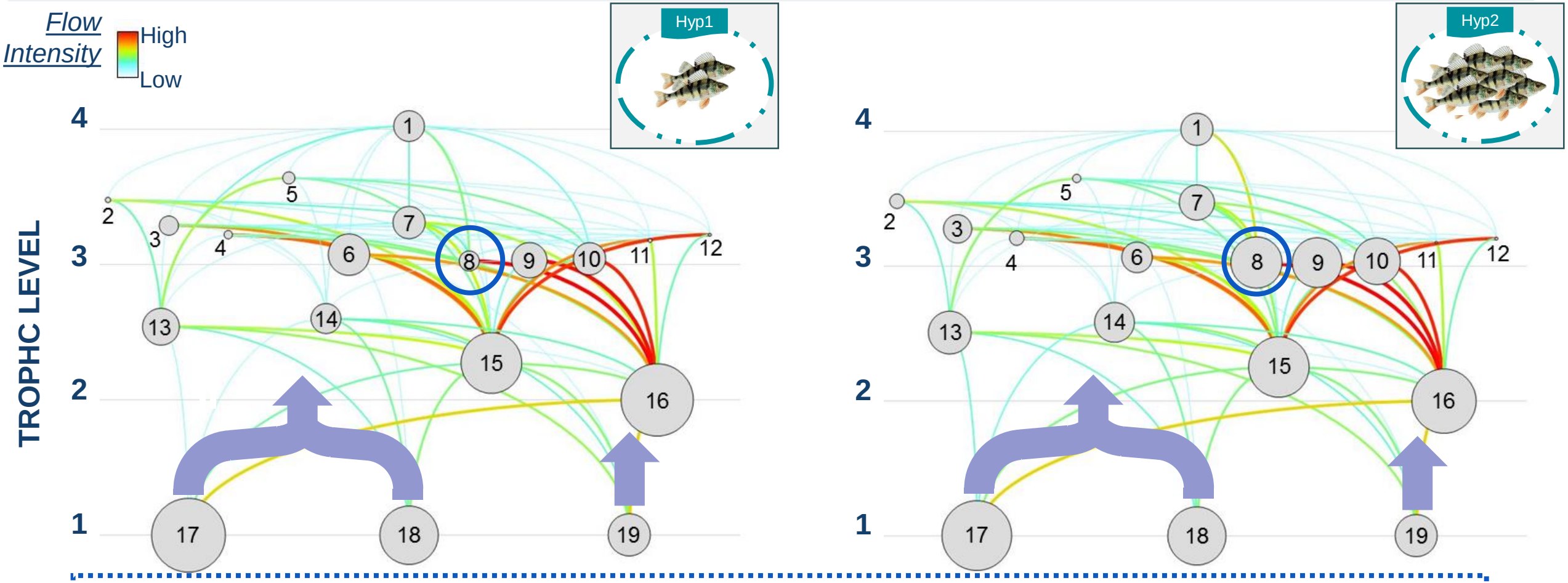
1. Pike	*5. Trout*	*9. Whitefish + 37*	*13. Roach*	*17. Phytoplankton*
2. Burbot	*6. Tench*	*10. Whitefish - 37*	*14. Cyprinids*	*18. Macrophytes*
3. Arctic charr + 26	*7. Perch*	*11. Bullhead*	*15. Zoobenthos*	*19. Detritus*
4. Arctic charr – 26	*8. Perch YOY*	*12. Blenny*	*16. Zooplankton*	

➔ Intensity of flows and relative biomass are comparable (except for YOY perch)

➔ Two origins for organic matter

➔ More than half of flows circulating in the system are from the detritus

STRUCTURE AND FUNCTIONING OF LAKE ANNECY FOOD WEB



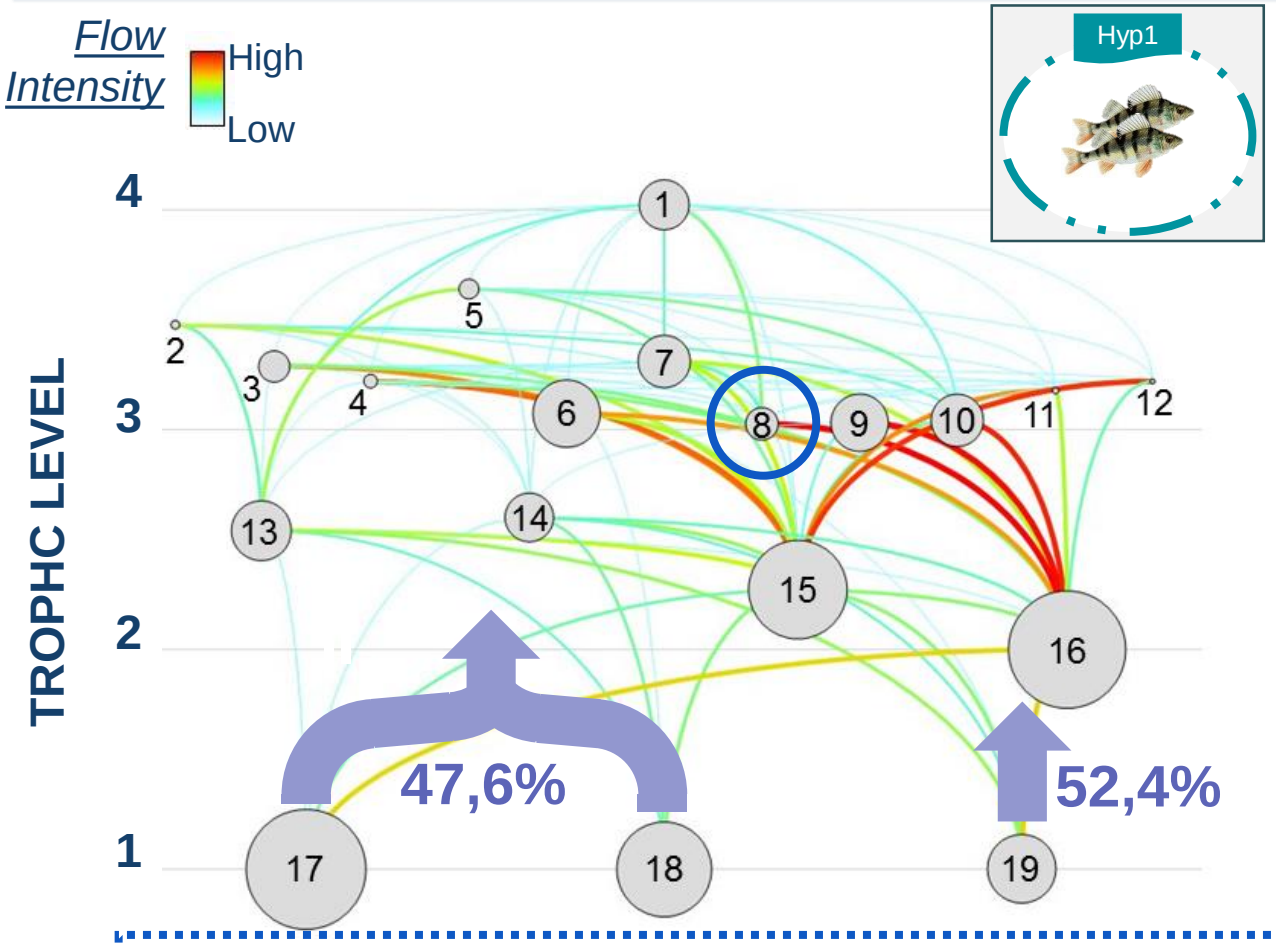
1. Pike	*5. Trout*	*9. Whitefish + 37*	*13. Roach*	*17. Phytoplankton*
2. Burbot	*6. Tench*	*10. Whitefish - 37*	*14. Cyprinids*	*18. Macrophytes*
3. Arctic charr + 26	*7. Perch*	*11. Bullhead*	*15. Zoobenthos*	*19. Detritus*
4. Arctic charr – 26	*8. Perch YOY*	*12. Blenny*	*16. Zooplankton*	

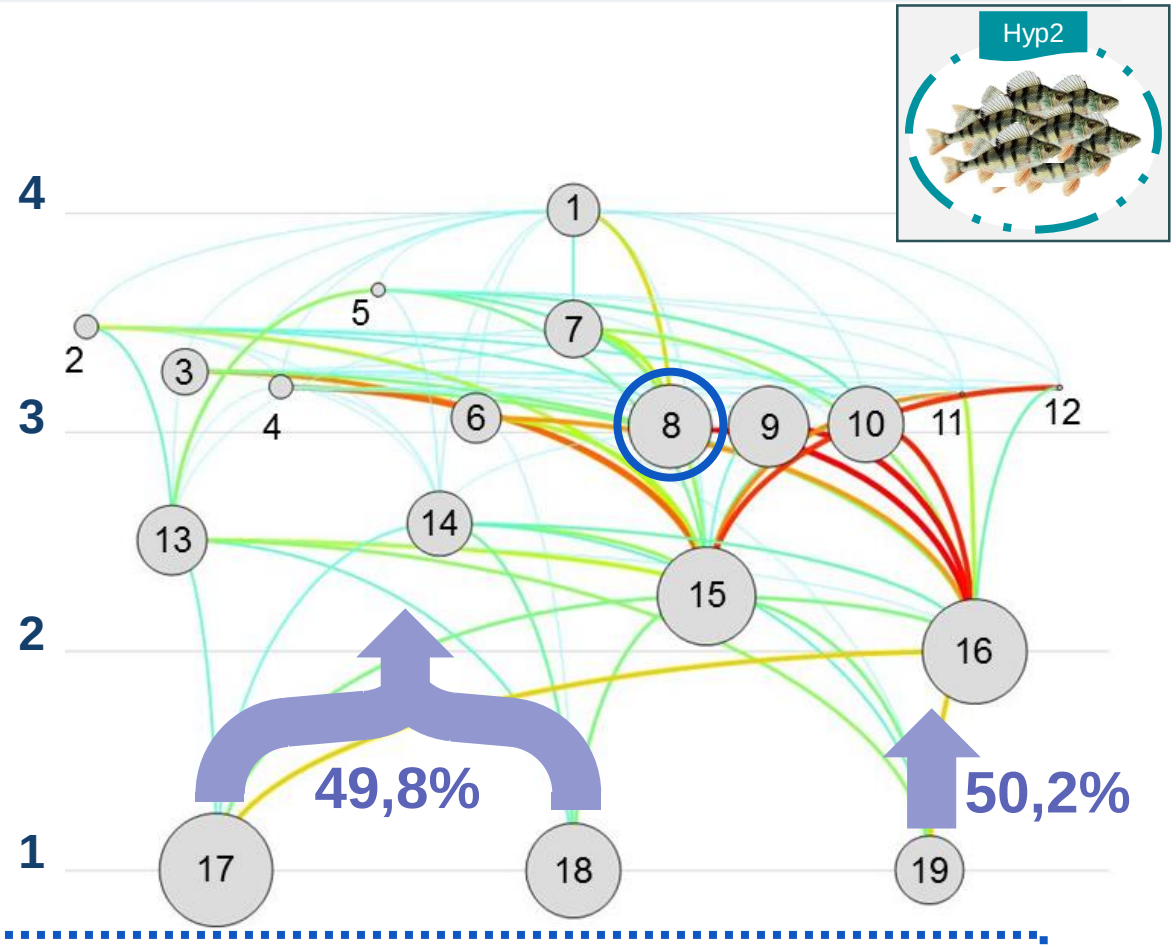
➔ Intensity of flows and relative biomass are comparable (except for YOY perch)

➔ Two origins for organic matter

➔ More than half of flows circulating in the system are from the detritus

STRUCTURE AND FUNCTIONING OF LAKE ANNECY FOOD WEB





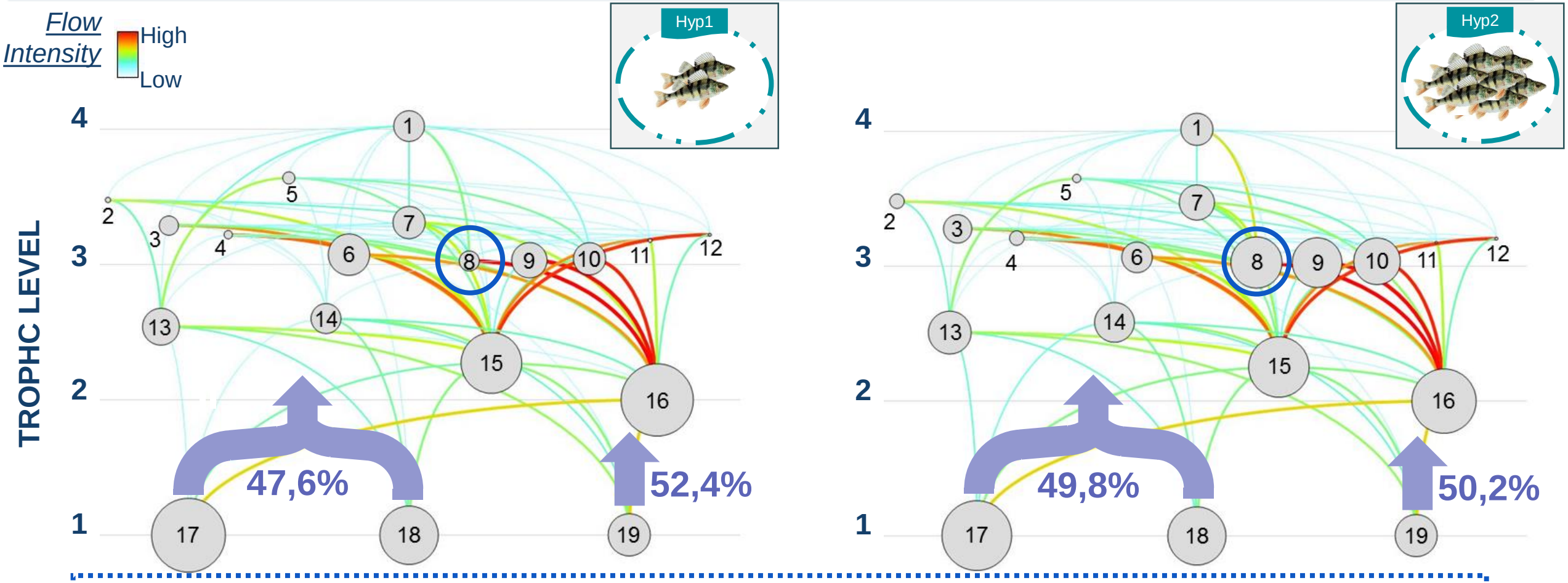
1. Pike	5. Trout	9. Whitefish + 37	13. Roach	17. Phytoplankton
2. Burbot	6. Tench	10. Whitefish - 37	14. Cyprinids	18. Macrophytes
3. Arctic charr + 26	7. Perch	11. Bullhead	15. Zoobenthos	19. Detritus
4. Arctic charr – 26	8. Perch YOY	12. Blenny	16. Zooplankton	

➔ Intensity of flows and relative biomass are comparable (except for YOY perch)

➔ Two origins for organic matter

➔ More than half of flows circulating in the system are from the detritus

STRUCTURE AND FUNCTIONING OF LAKE ANNECY FOOD WEB



1. Pike	*5. Trout*	*9. Whitefish + 37*	*13. Roach*	*17. Phytoplankton*
2. Burbot	*6. Tench*	*10. Whitefish - 37*	*14. Cyprinids*	*18. Macrophytes*
3. Arctic charr + 26	*7. Perch*	*11. Bullhead*	*15. Zoobenthos*	*19. Detritus*
4. Arctic charr – 26	*8. Perch YOY*	*12. Blenny*	*16. Zooplankton*	

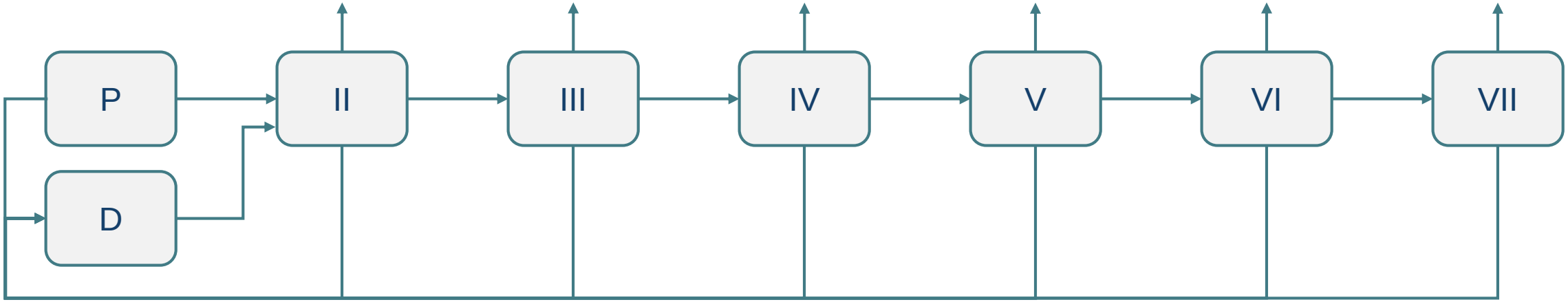
➔ Intensity of flows and relative biomass are comparable (except for YOY perch)

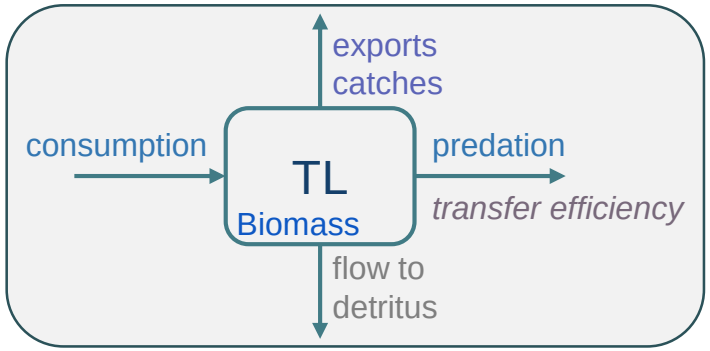
➔ Two origins for organic matter

➔ More than half of flows originating from the detritus

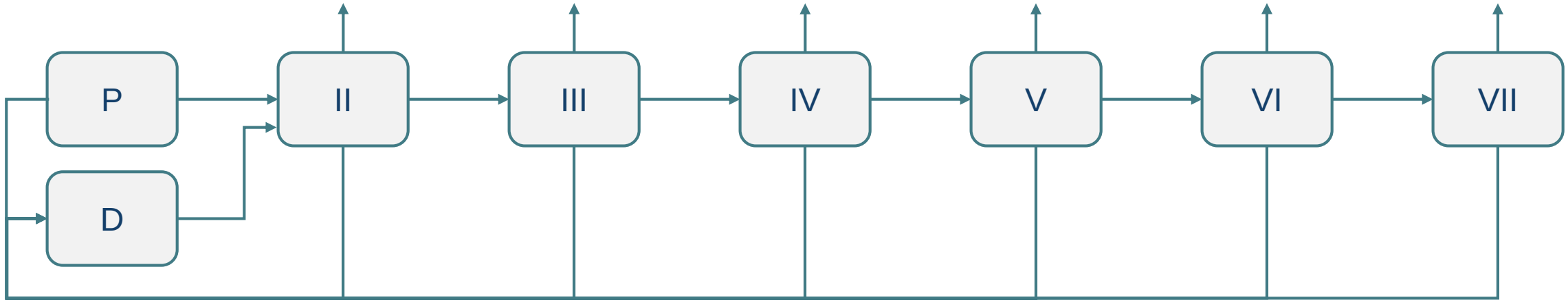
Structure and global functioning are similar

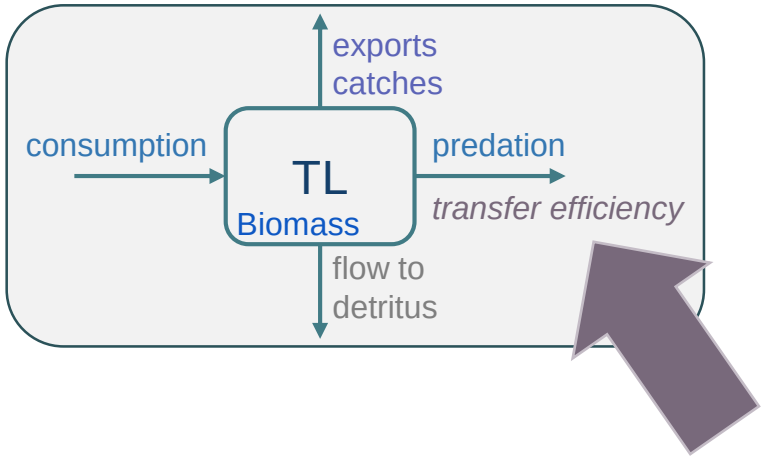
EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



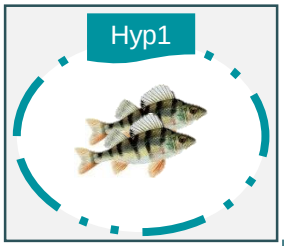


EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



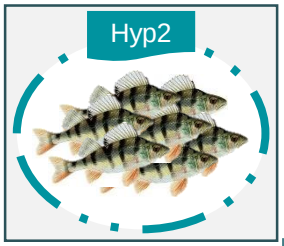


EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



5,98%

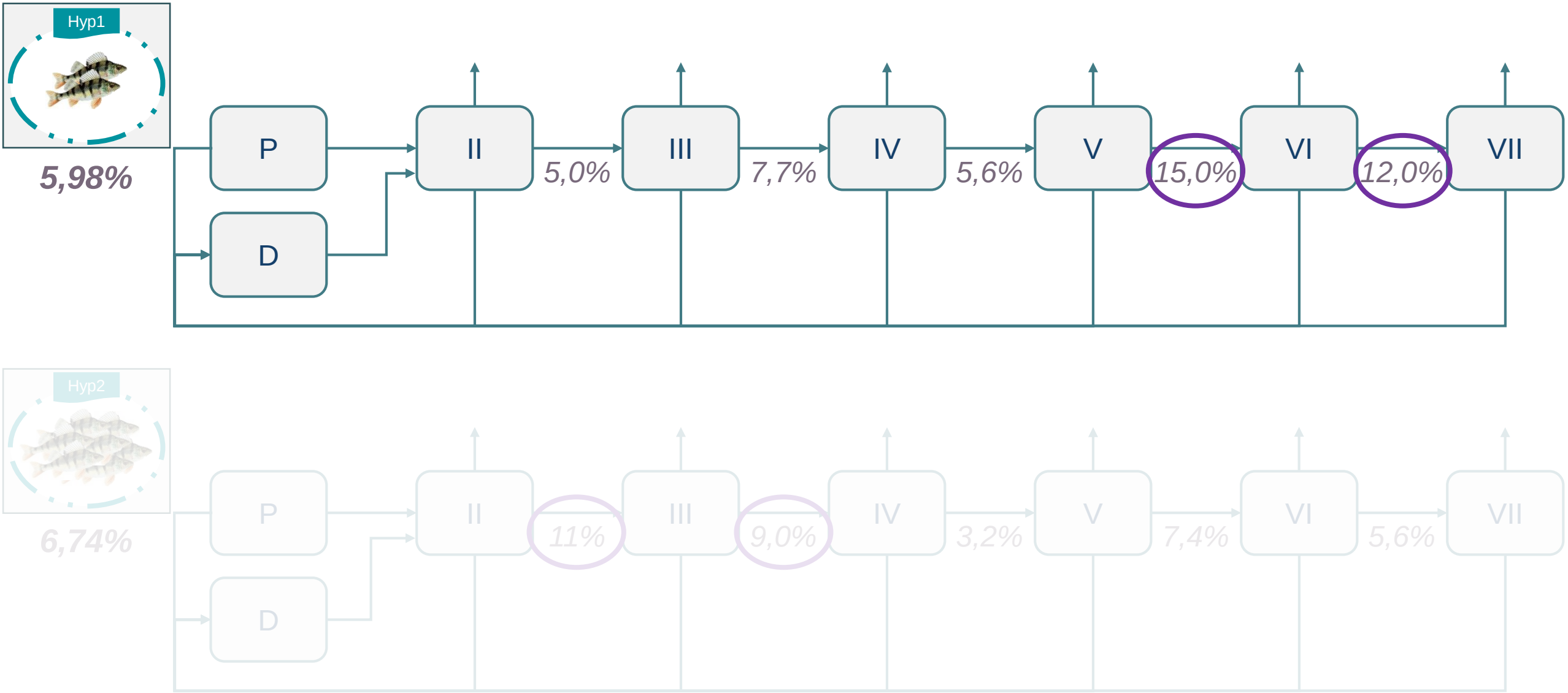
P
D
II
5,0%
III
7,7%
IV
5,6%
V
15,0%
VI
12,0%
VII



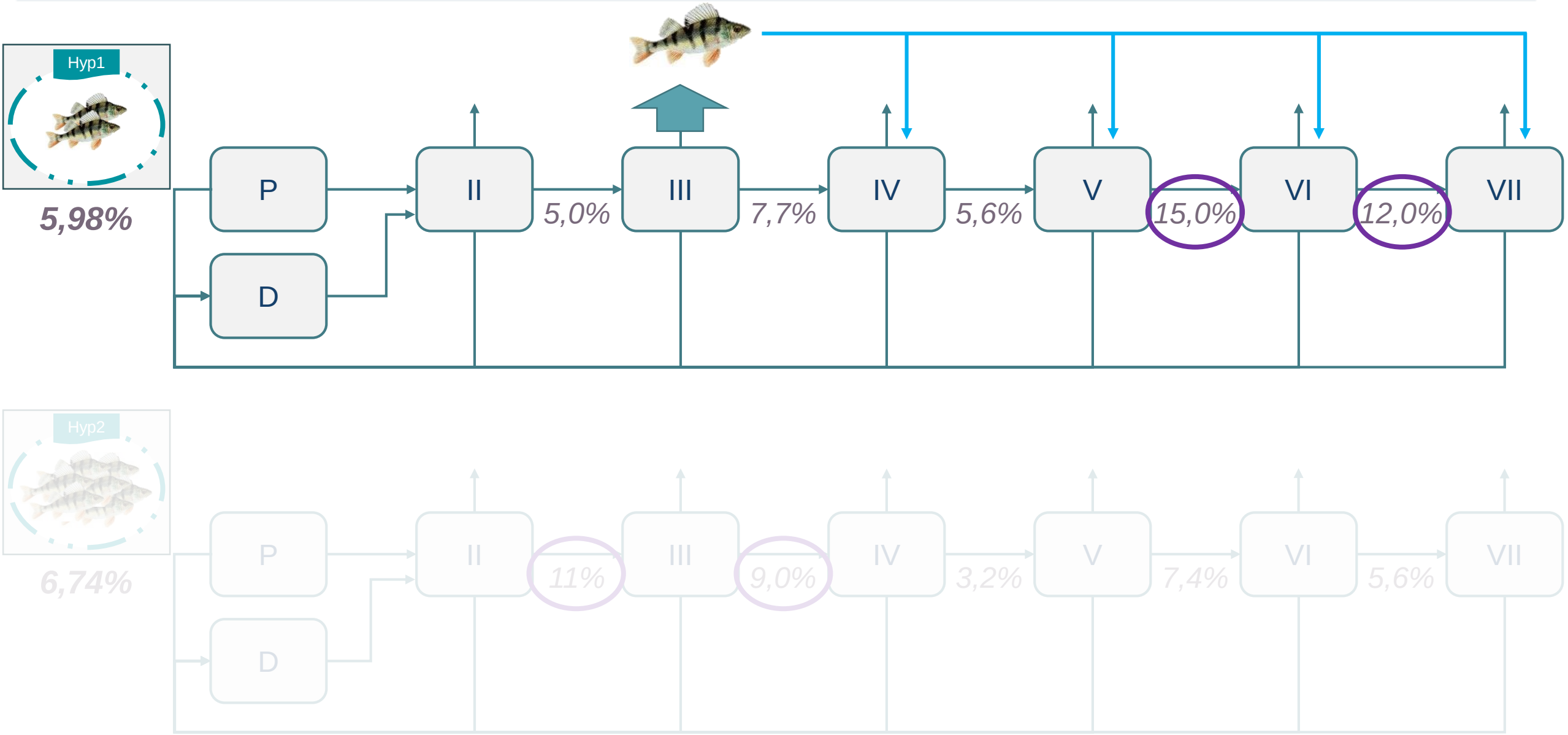
6,74%

P
D
II
11%
III
9,0%
IV
3,2%
V
7,4%
VI
5,6%
VII

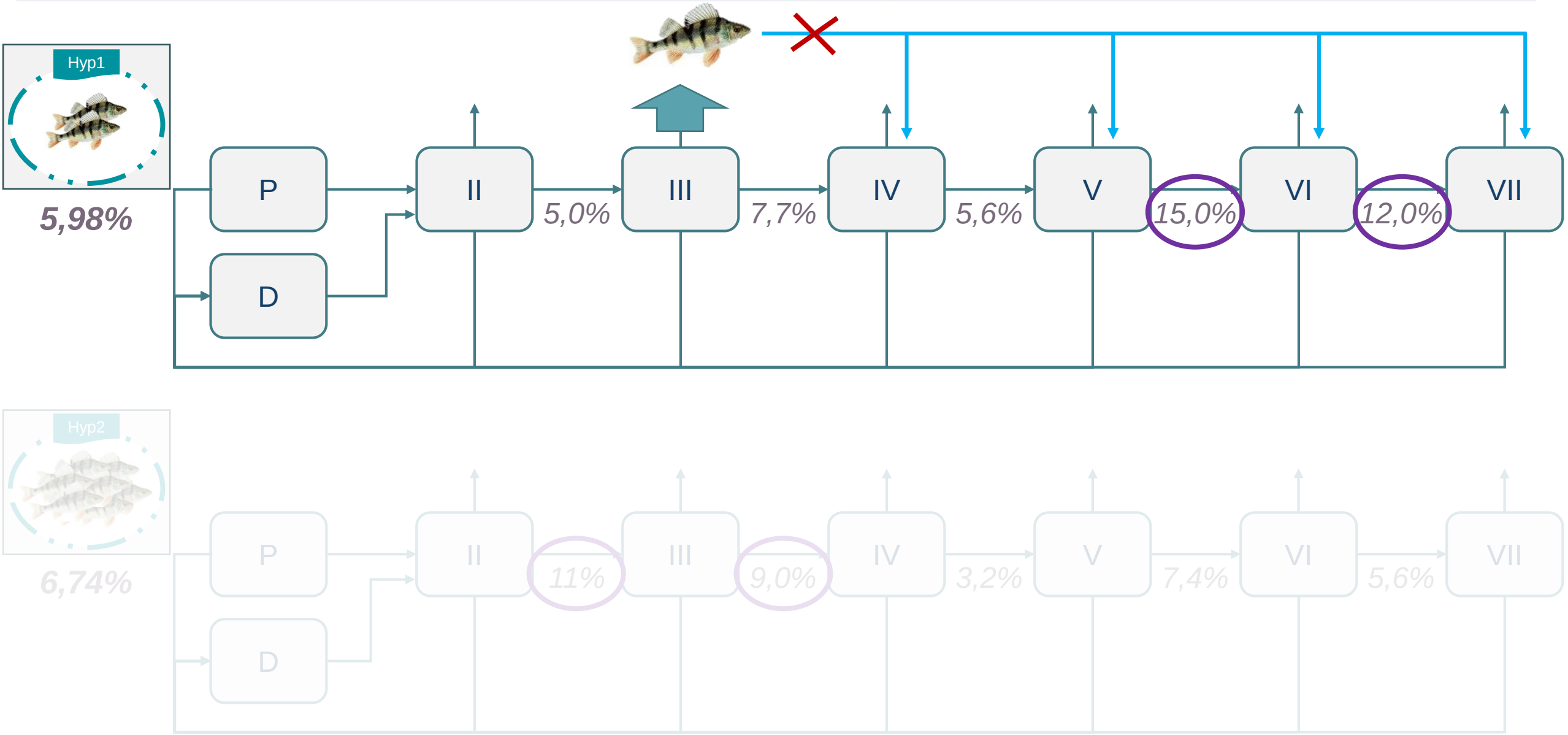
EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



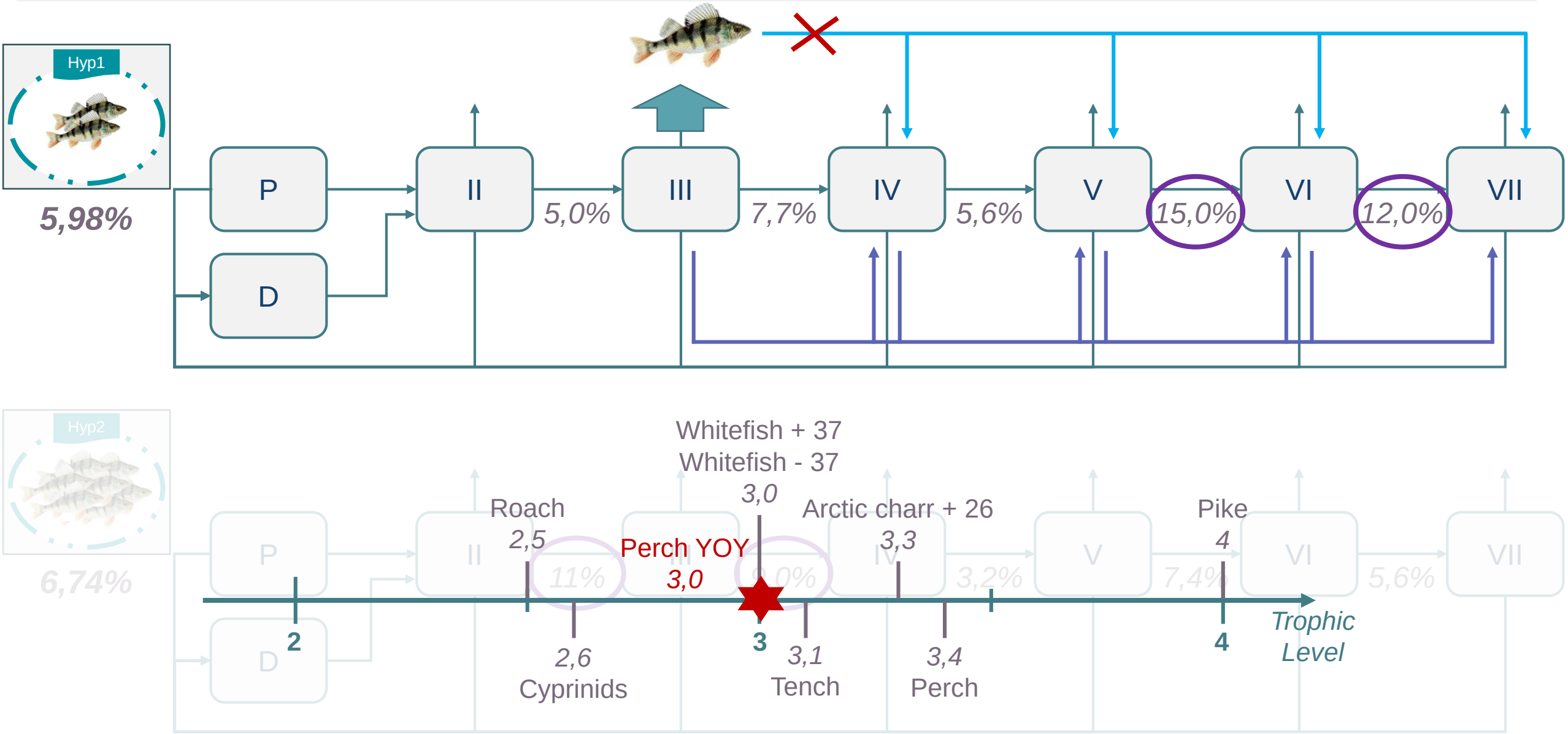
EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB

5,98%

P

D

II

5,0%

III

7,7%

IV

5,6%

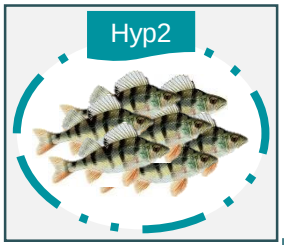
V

15,0%

VI

12,0%

VII



6,74%

P

D

II

11%

III

9,0%

IV

3,2%

V

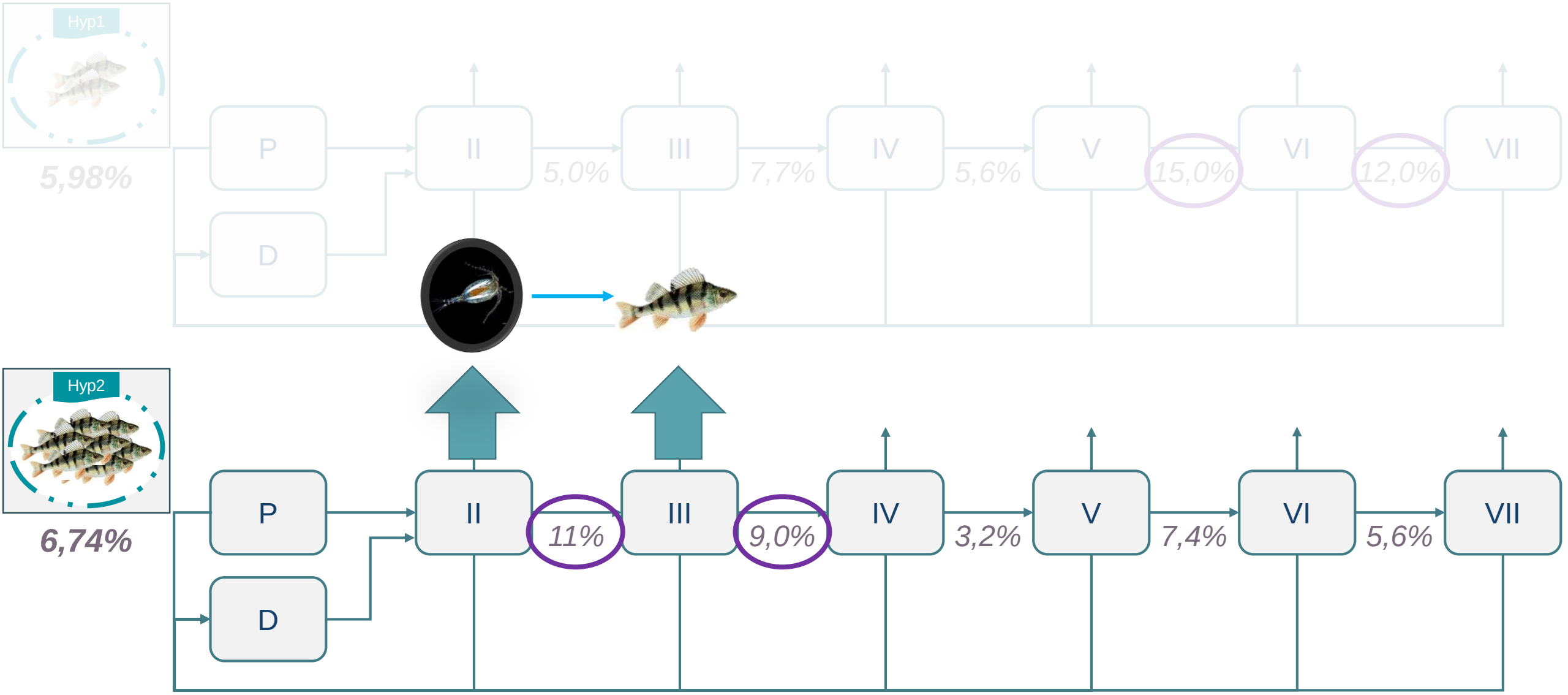
7,4%

VI

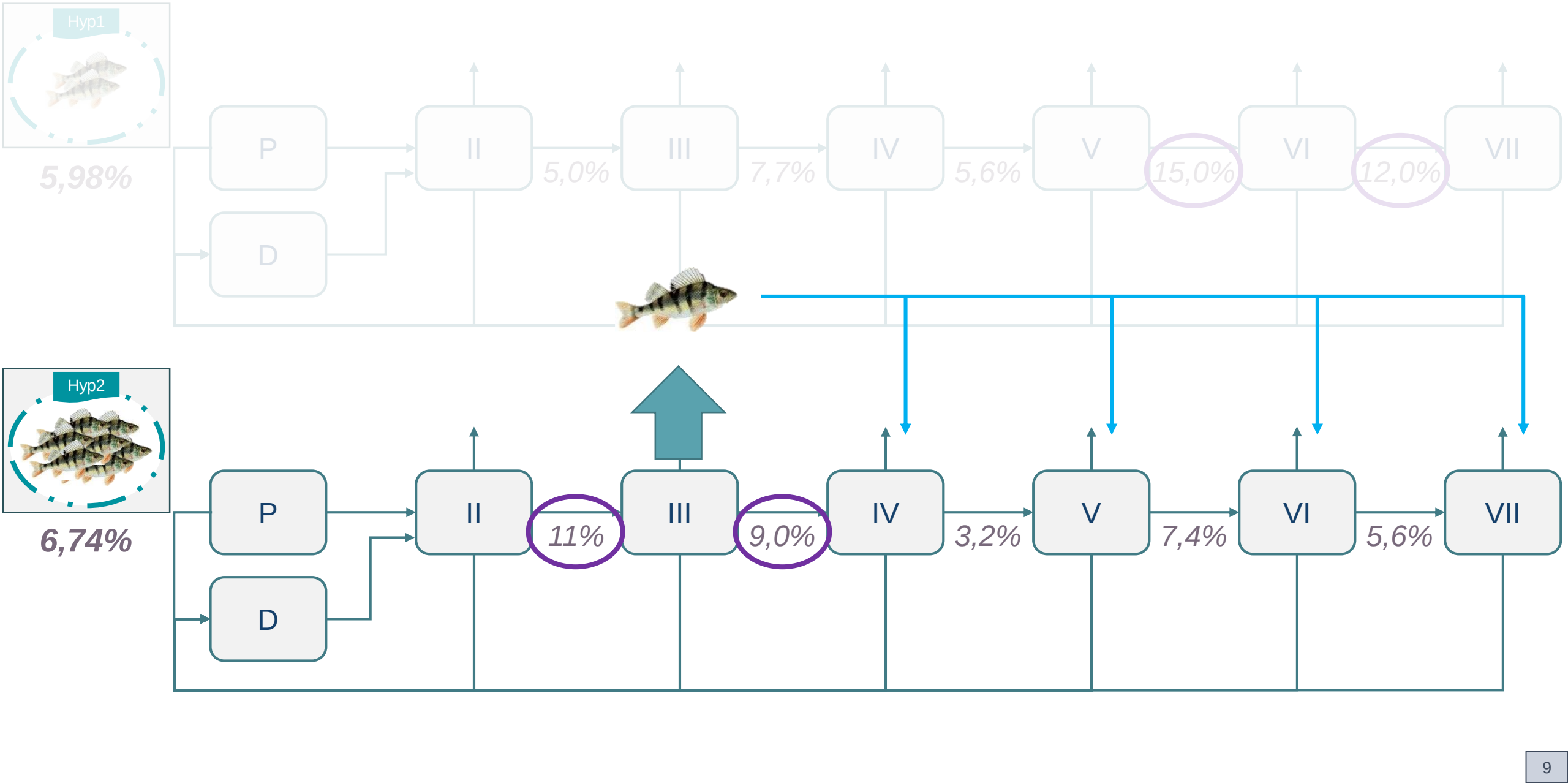
5,6%

VII

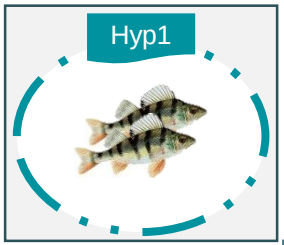
EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB

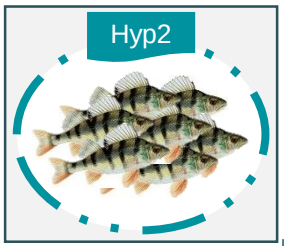


EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



5,98%

P
D
II
III
IV
V
VI
VII
5,0%
7,7%
5,6%
15,0%
12,0%



6,74%

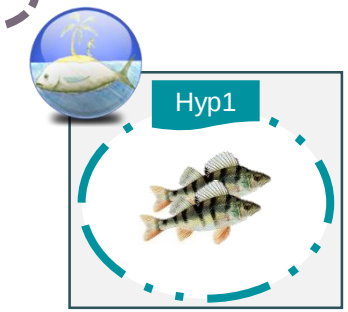
P
D
II
III
IV
V
VI
VII
11%
9,0%
3,2%
7,4%
5,6%

➔ **Variation in the functioning of the food web**
➔ **YOY perch facilitates transfers from low to high trophic level**

II. MINIMUM AND MAXIMUM YOY PERCH BIOMASS ACCEPTABLE FOR LAKE ANNECY ECOSYSTEM

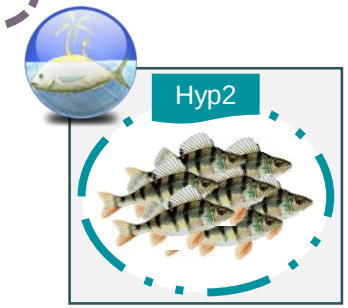
MATERIAL & METHOD: Ecopath model – MODELS COMPARISON

1



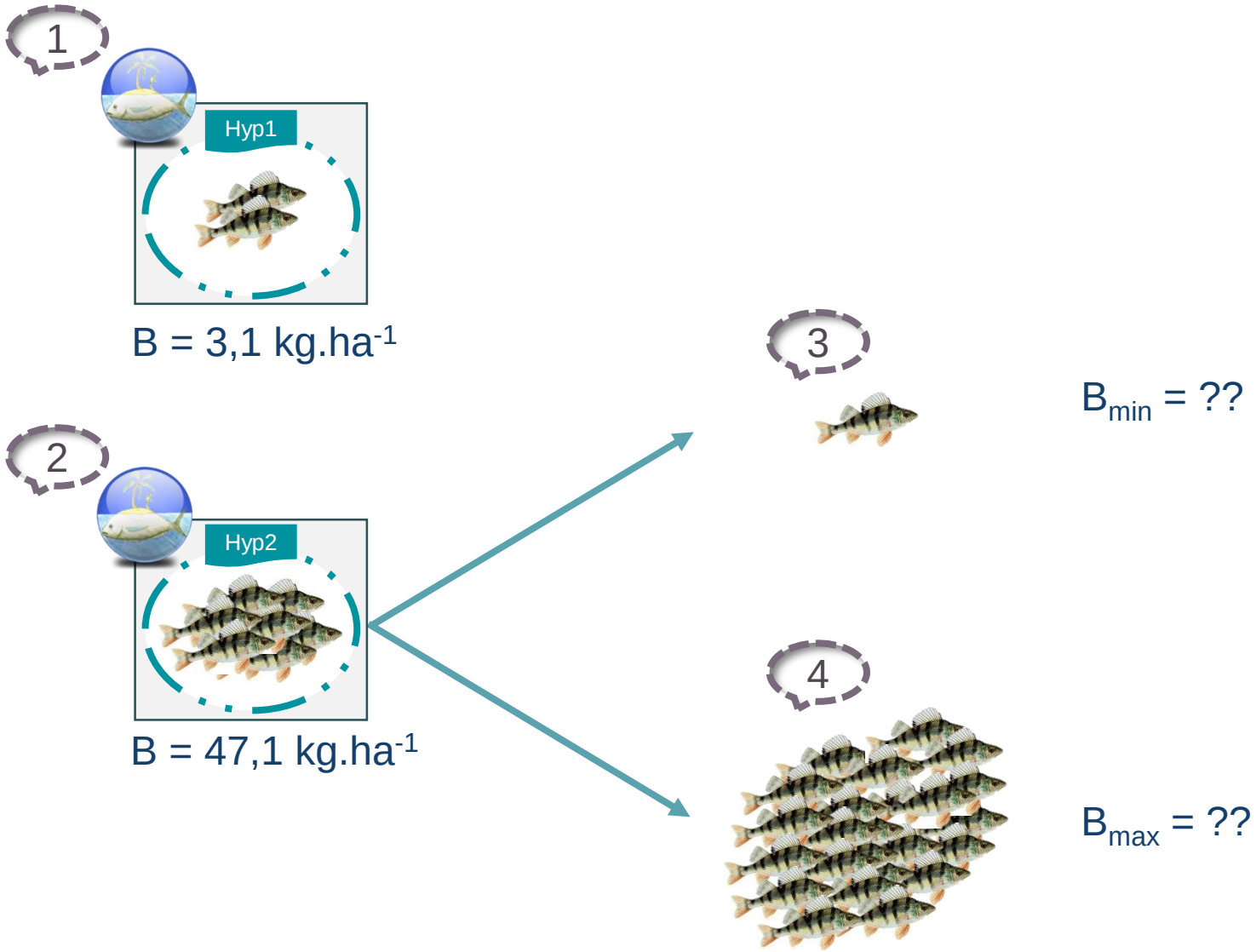
B = 3,1 kg.ha^{-1}

2

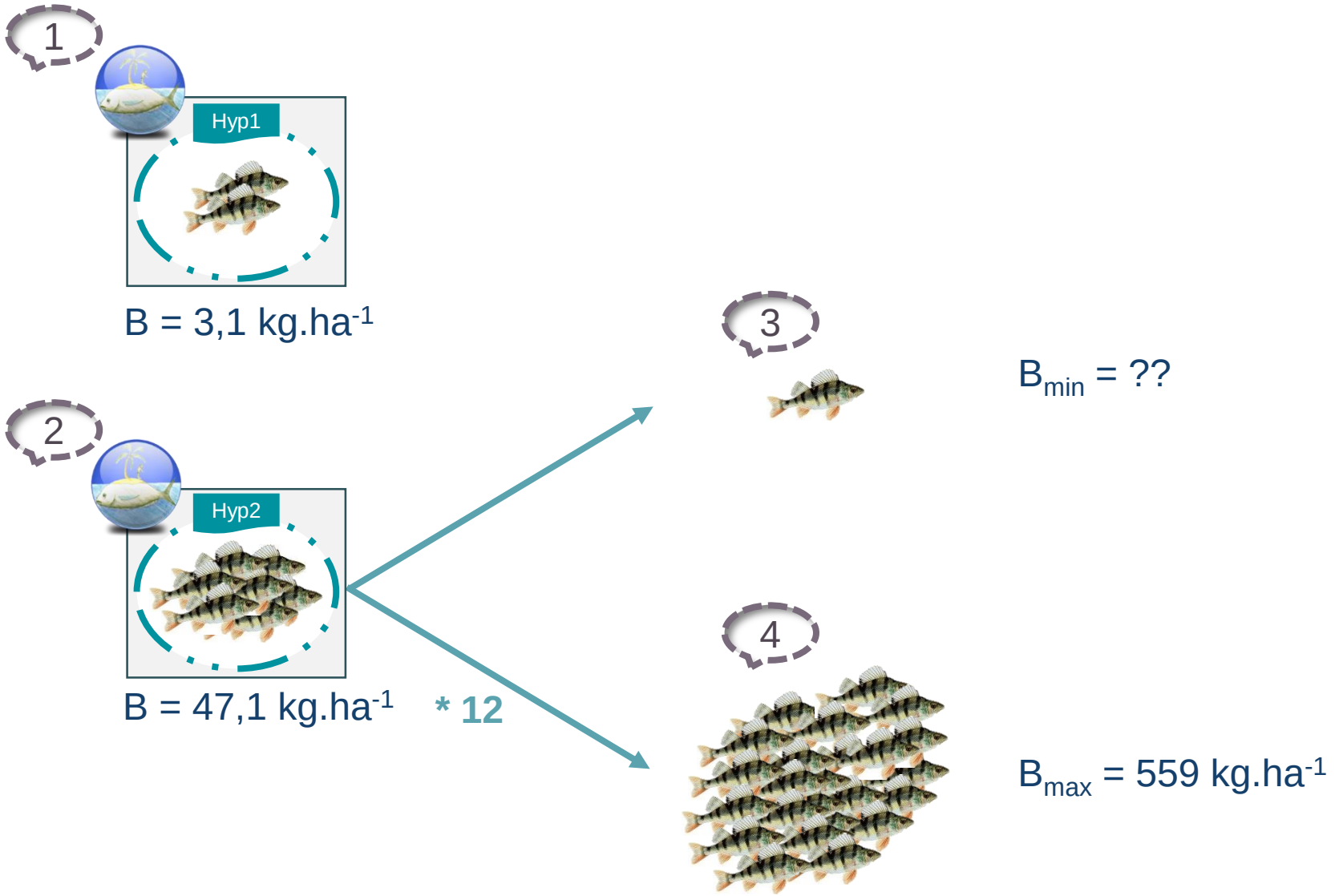


B = 47,1 kg.ha^{-1}

MATERIAL & METHOD: Ecopath model – MODELS COMPARISON



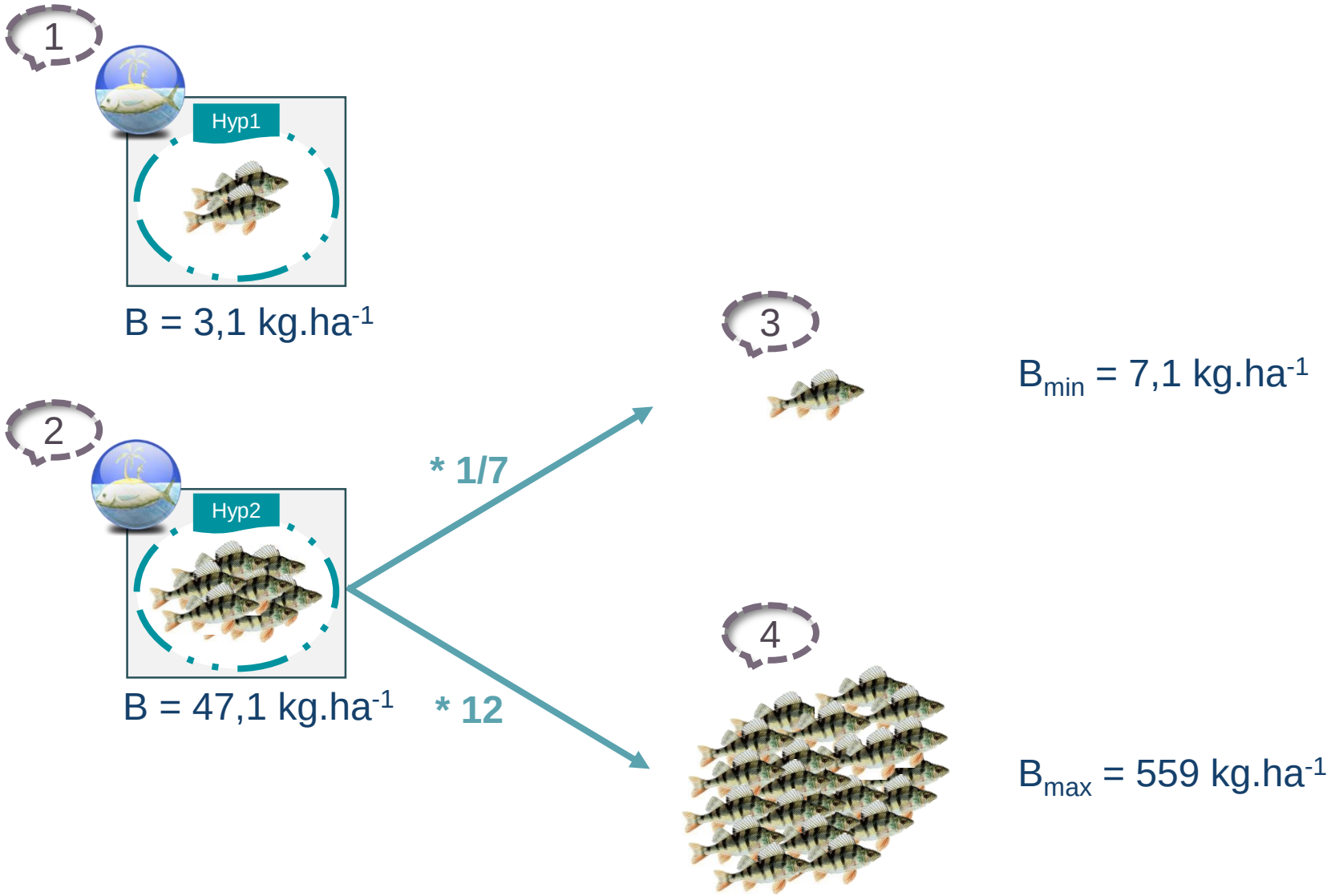
MATERIAL & METHOD: Ecopath model – MODELS COMPARISON



➔ Good carrying capacity for YOY perch

➔ Good capacity of the system to handle strong variations in YOY perch biomass

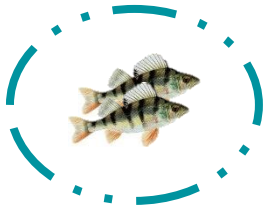
MATERIAL & METHOD: Ecopath model – MODELS COMPARISON

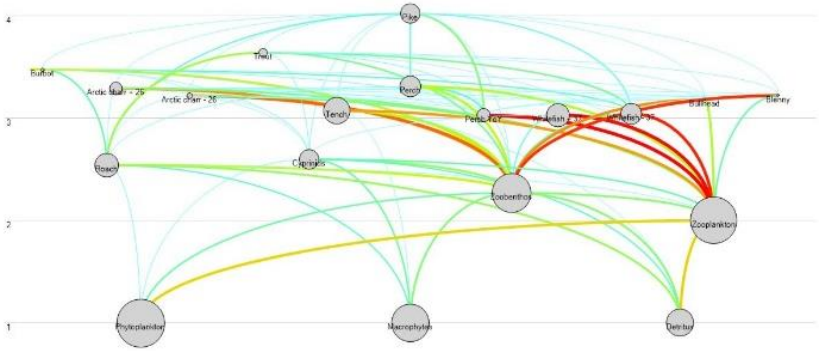


➔ Good carrying capacity for YOY perch

➔ Good capacity of the system to handle strong variations in YOY perch biomass

CONCLUSIONS ON LAKE ANNECY FOOD WEB





Similar structure and global functioning of food web in both year

Key contribution of YOY perch in transfers

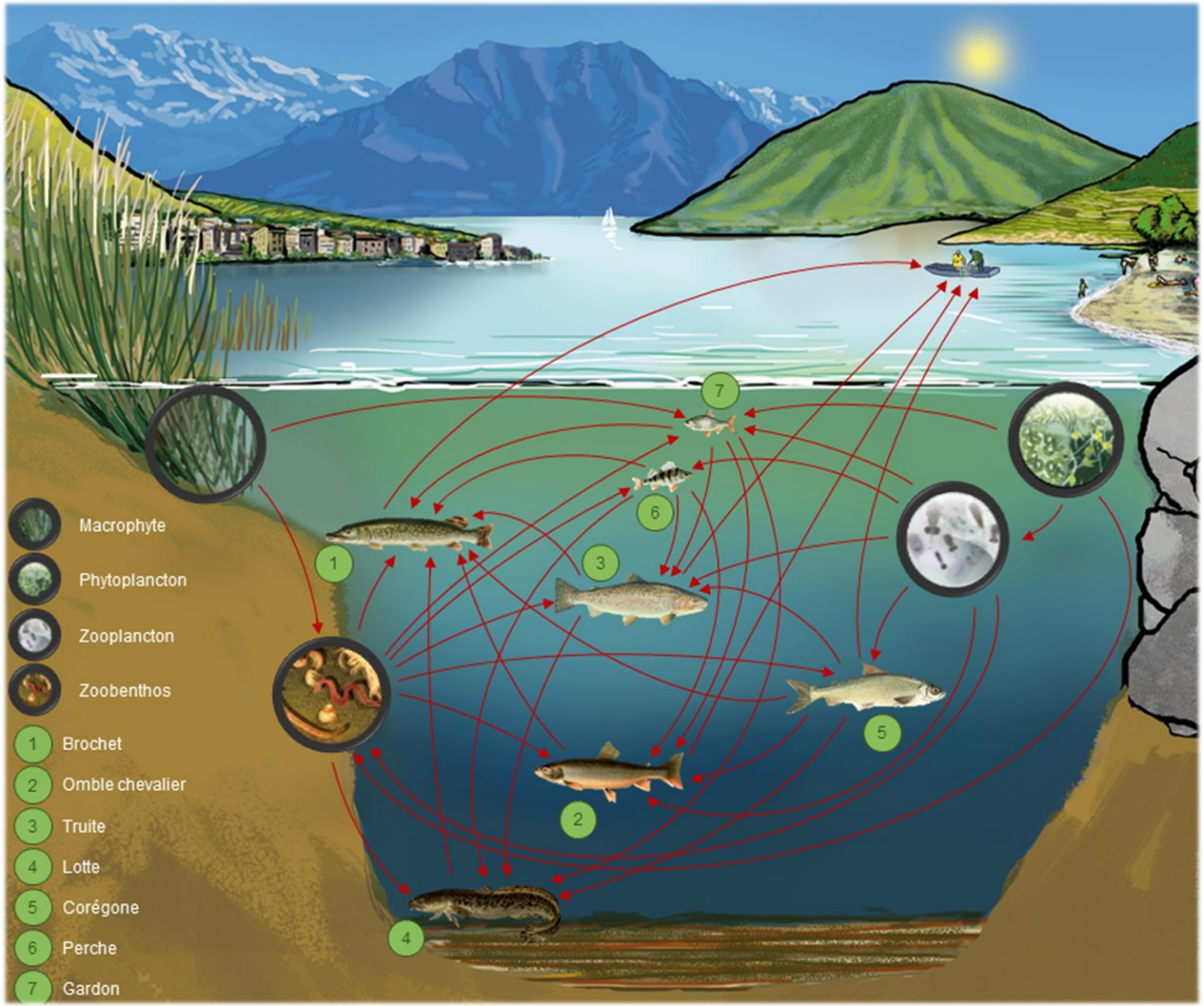
Stability of Lake Annecy food web
Capacity to tolerate strong variations of YOY perch biomass

Resilience of Lake Annecy food web to **extreme events** in intermediate trophic level abundance
Networked structure, predation report…

Substantial fish **omnivory** stabilzed an ecosystem


Thank you for your attention

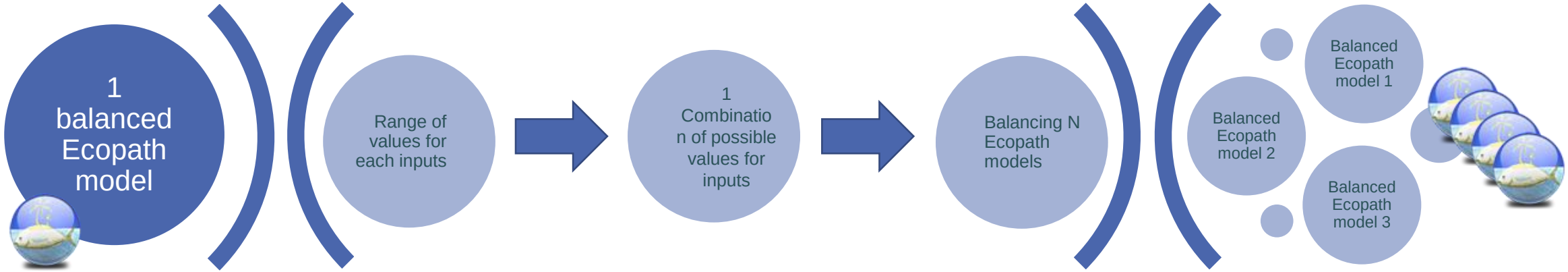
CONTEXTUAL BACKGROUND: Young Of the Year (YOY) Perch



Lake Annecy food web

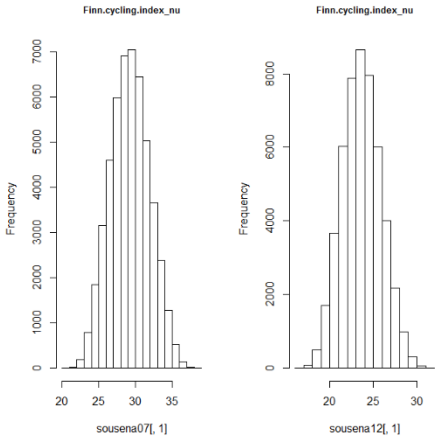
La routine ENA Tool – incertitude routine

1 Ecopath model ⇔ 1 value per output



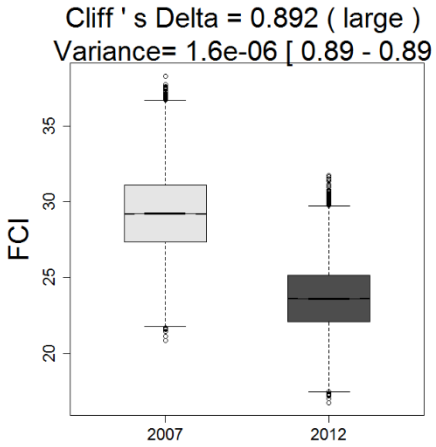
➔ 50 000 balanced models → 50 000 outputs packages

Distribution of the indices



Delta de Cliff: caracterize the difference between the distributions *(Romano et al., 2006)*
Large > Medium > Small > Negligible

Comparing the two years



Guesnet et al. (2015). Incorporating food-web parameter uncertainty into Ecopath-derived ecological network indicators.

MATERIAL & METHOD: Ecopath model - BALANCING

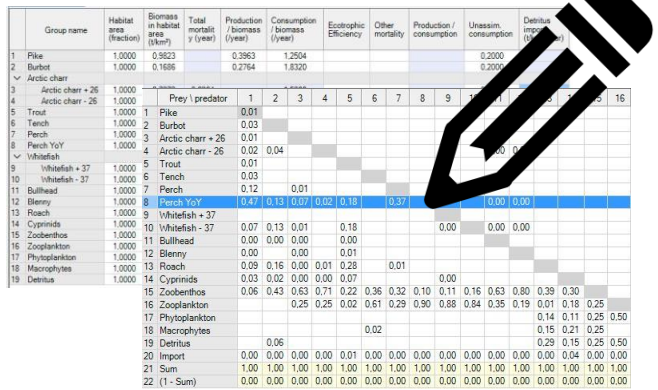
Ecotrophic efficiency (EE) = parameter computed by Ecopath for each group = fraction of the group which is used by the system **< 1**

Basic outputs

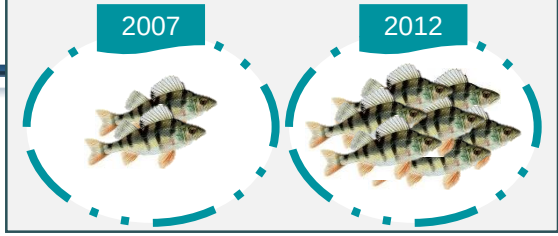
	Group name	Trophic level	Habitat area (fraction)	Biomass in habitat area (t/km²)	Biomass (t/km²)	Z (/year)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Production / consumption
1	Pike	4,026	1,000	1,059	1,059		0,366	1,581	0,218	0,232
2	Burbot	3,487	1,000	0,0485	0,0485		0,220	1,679	9,559	0,131
	Artic charr									
3	Artic charr +26	3,308	1,000	0,314	0,314	0,482		1,769	0,548	0,272
4	Artic charr -26	3,206	1,000	0,0280	0,0280	0,259		4,588	7,667	0,056
5	Trout	3,650	1,000	0,054	0,054		0,939	1,174	0,800	0,800
6	Tench	3,066	1,000	0,830	0,830		0,647	2,766	0,097	0,234
7	Perch	3,473	1,000	1,355	1,355		0,329	2,271	0,636	0,145
8	Perch YoY	3,025	1,000	5,419	5,419		0,329	2,271	1,116	0,145
	Whitefish									
9	Whitefish +37	3,030	1,000	2,159	2,159	0,804		1,769	0,348	0,454
10	Whitefish -37	3,040	1,000	2,125	2,125	0,524		2,663	0,132	0,197
11	Bullhead	3,174	1,000	0,000350	0,000350		0,698	4,900	15,656	0,142
12	Blenny	3,205	1,000	0,00131	0,00131		0,681	5,648	2,274	0,121
13	Roach	2,508	1,000	2,481	2,481		0,370	2,775	0,262	0,133
14	Cyprinids	2,584	1,000	1,926	1,926		0,274	3,698	0,123	0,074
15	Zoobenthos	2,250	1,000	9,639	9,639		5,200	26,000	0,197	0,200
16	Zooplankton	2,000	1,000	13,04	13,04		19,00	69,091	0,346	0,275
17	Phytoplankton	1,000	1,000	20,32	20,32		32,90		0,770	
18	Macrophytes	1,000	1,000	7,251	7,251		10,000		0,900	
19	Detritus	1,000	1,000	2,200	2,200				0,616	

Progressive adjustment

Inputs: Basic inputs + DC



SIMILAR STRUCTURE AND FUNCTIONING OF LAKE ANNECY FOOD WEB

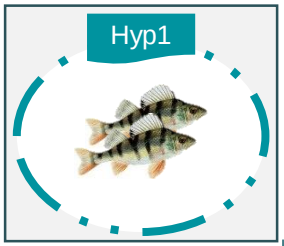


Main transfer paths

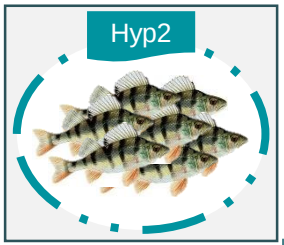
6 transfers maximum

Phytoplankton	Zooplankton	YOY Perch Whitefish < 37 Whitefish > 37	Perch Trout /	Pike Pike /
Detritus	Zooplankton	YOY Perch Whitefish < 37 Whitefish > 37	Perch Trout /	Pike Pike /

EFFICIENCY OF TRANSFERS THROUGH THE FOOD WEB



5,98%



6,74%