Effects of hydrodynamic conditions on predation by fish and mating success of *Pseudodiaptomus annandalei* (Copepoda: Calanoida)

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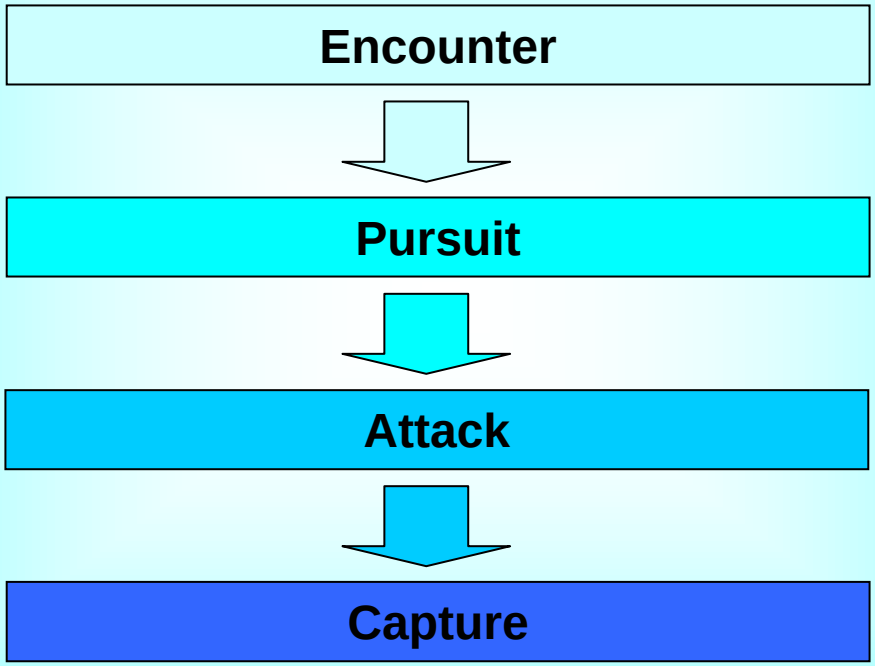
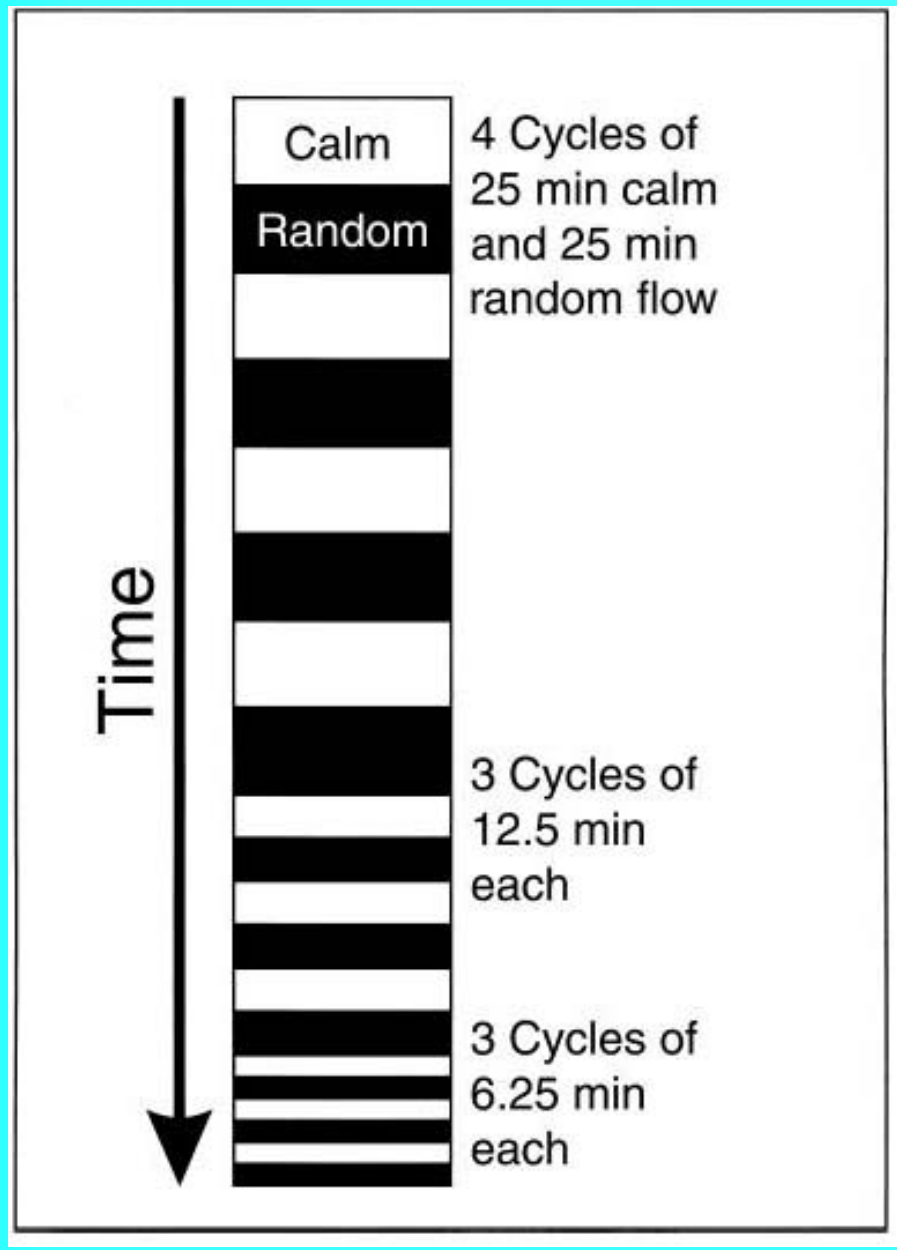
Behavioral sequence during a predator-prey interaction (MacKenzie et al., 1994):



… effect of hydrodynamic conditions?



Schematic diagram of the time course of a copepod exposed to periodic hydrodynamical stimuli

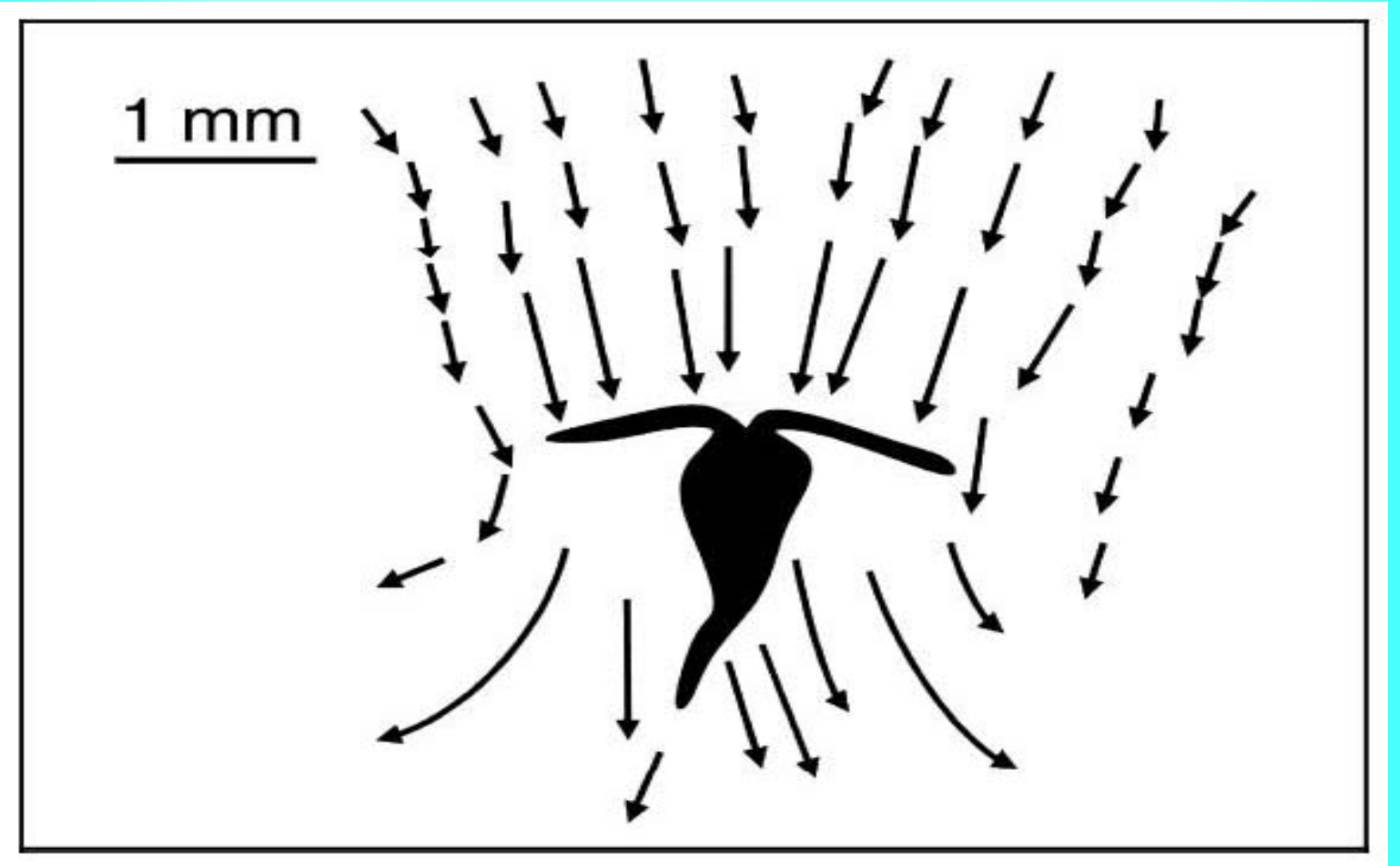
from Hwang & Strickler ZOOL STUD 2001, Fig. 1

Table 1. Particle speeds triggering copepod escape responses during the switch from calm to random flow. The data include 4 replications of the 25-min periods of random flow, and 3 replications each of the 12.5- and 6.25-min periods of random flow

25-min random flow periods			12.5-min random flow periods				6.25-min random flow periods		
particle speed triggering escape response (mm/s)			particle speed triggering escape response (mm/s)				particle speed triggering escape response (mm/s)		
0.84	4.15	4.29	0.87	3.99	4.96	5.42	6.89	8.00	10.99

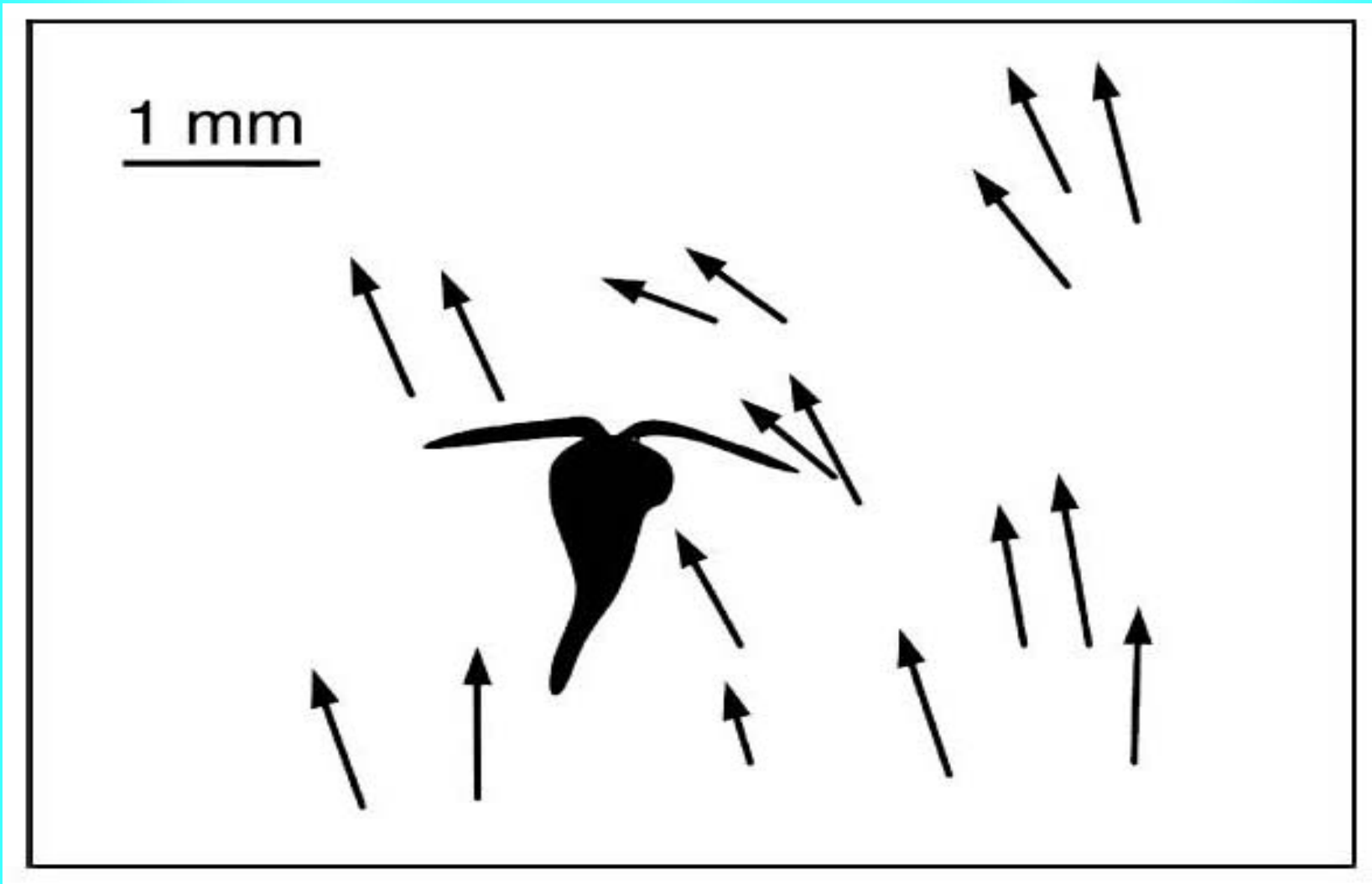
from Hwang & Strickler ZOOL STUD 2001, Tab. 1

Dorsal view of *Centropages hamatus* when generating a feeding current. Note the typical path of entraining particles. Each arrow shows the path line of a particle during a 1-s interval



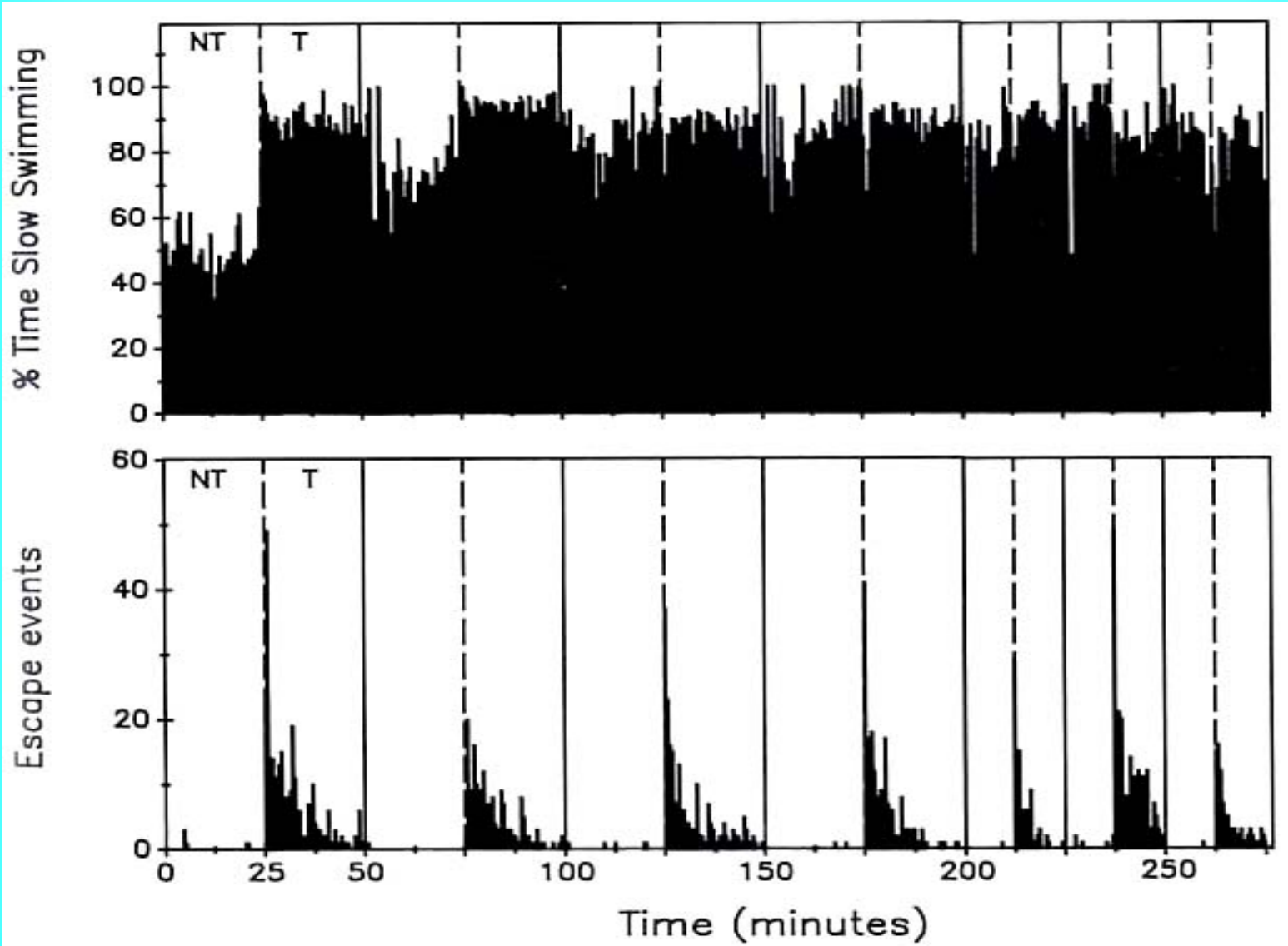
from Hwang & Strickler ZOOL STUD 2001, Fig. 2

Dorsal view of *Centropages hamatus* subjected to random flow milliseconds before initiating an escape reaction. Each arrow shows the path track of a particle during a 1 second interval



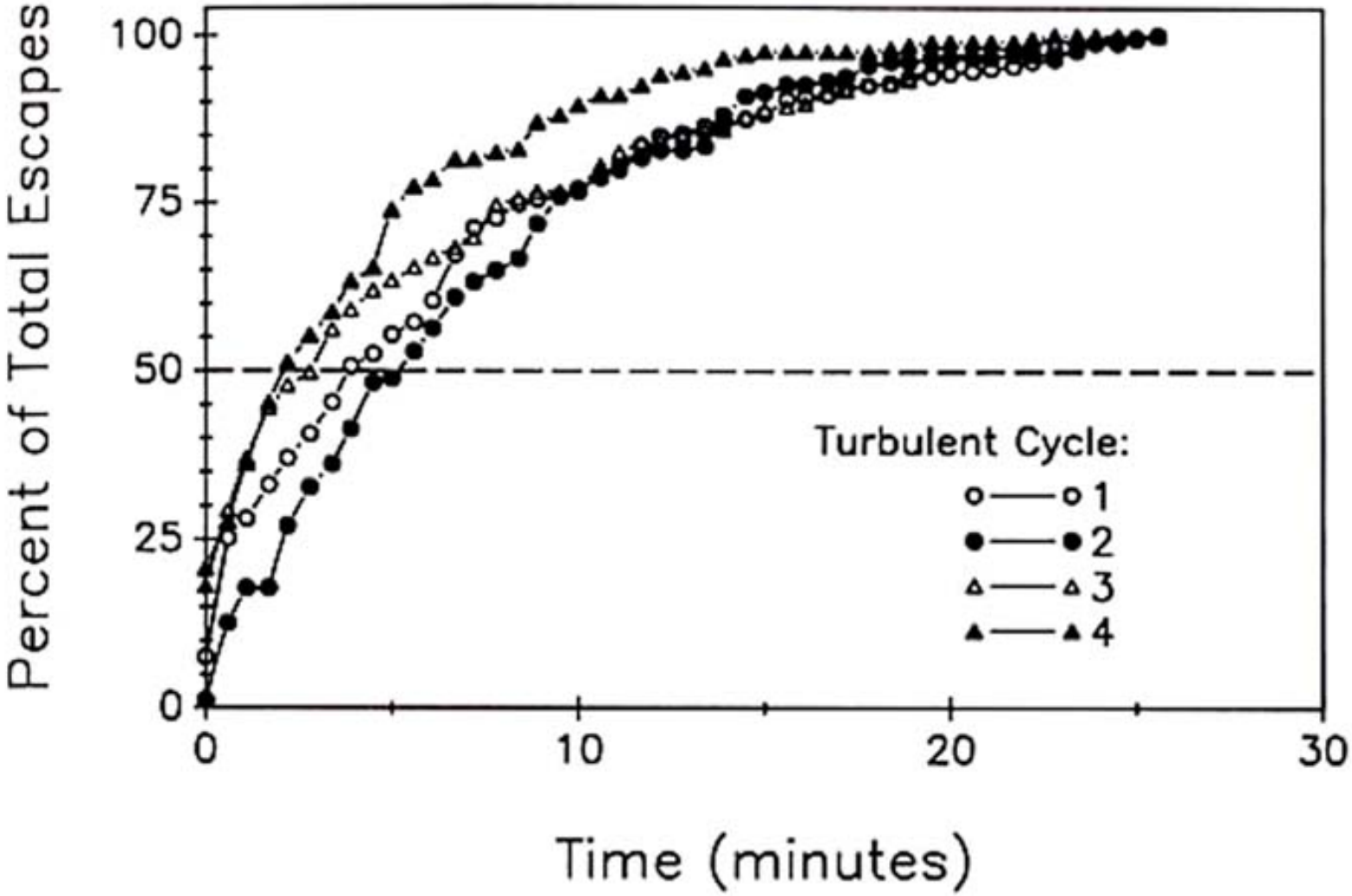
from Hwang & Strickler ZOOL STUD 2001, Fig. 3

Time course of a female *Centropages hamatus* exposed to periodic cycles of non-turbulent and turbulent flow



from Hwang et al. 1994, JPR, Fig. 1

Time course of the cumulative per cent of total escape events occurring during the 25 min duration turbulent cycles



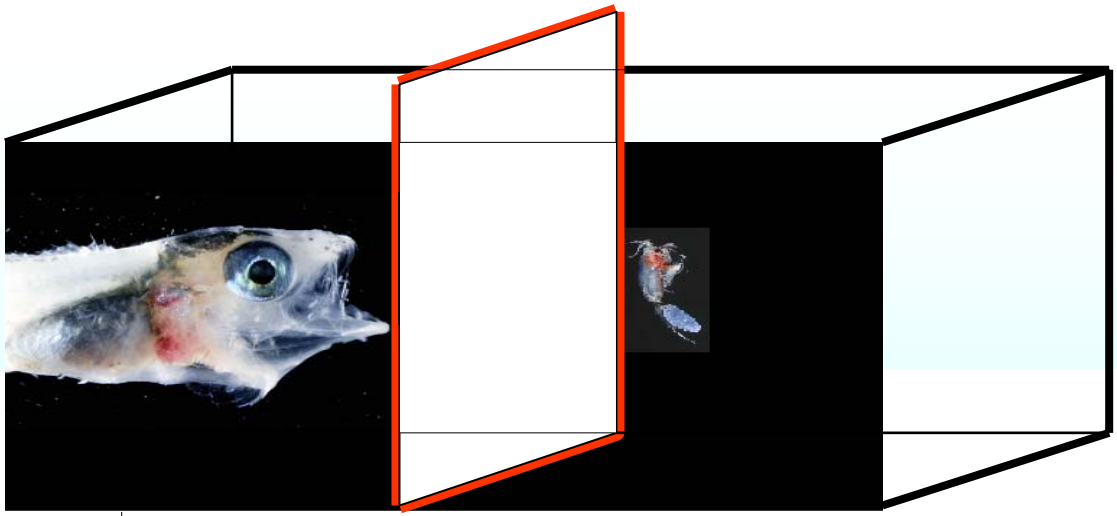
from Hwang et al. 1994, JPR, Fig. 3

OBJECTIVES:

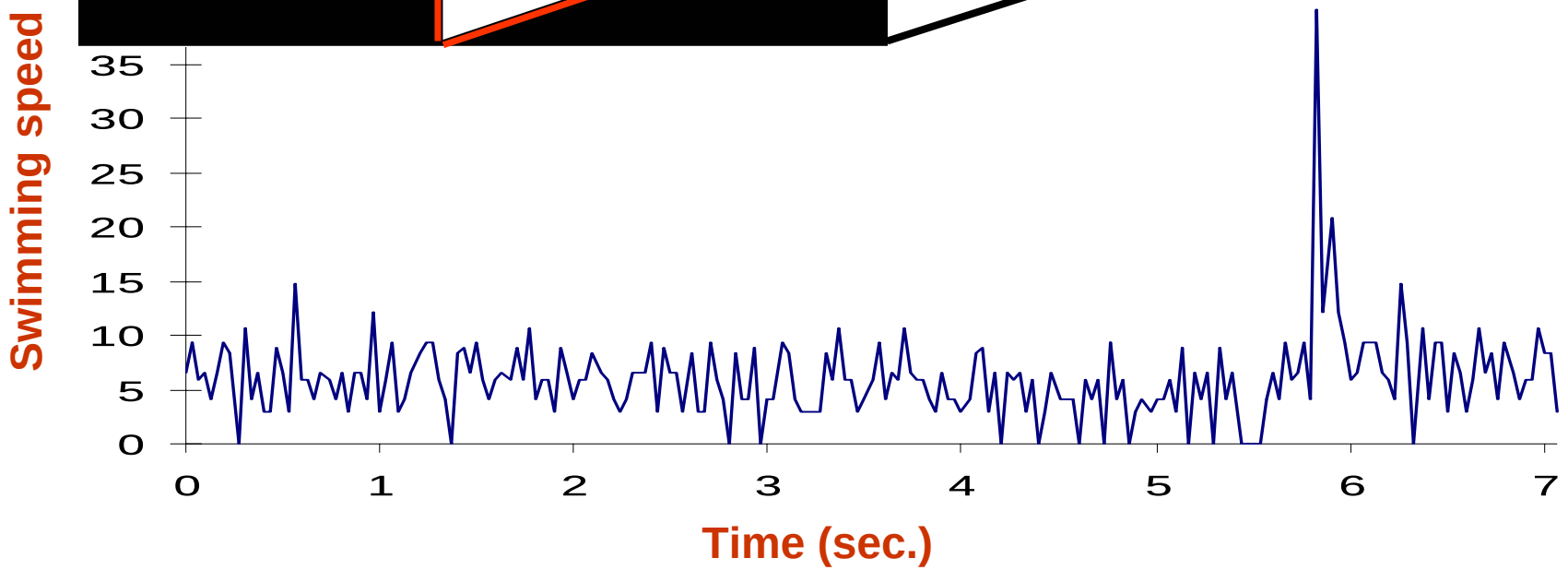
To understand:

- the predatory efficiency as a function of escape ability of the calanoid copepod *Pseudodiaptomus annandalei* from its common fish larval predator
- mating behavior under different hydrodynamic conditions

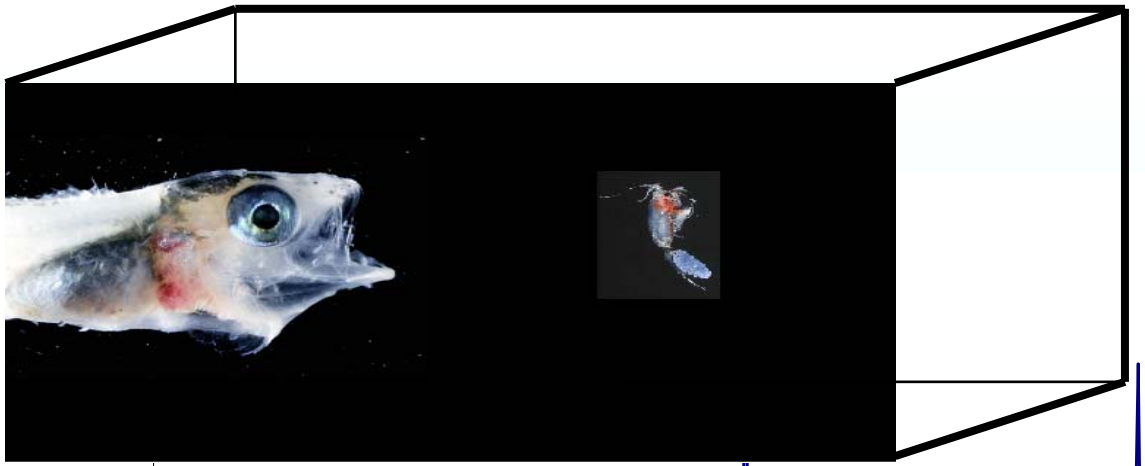
Swimming speed of copepods **(n=30)** when fish larvae are isolated by a transparent acrylic plate



5.5±1.6 mm/sec. (n=30)



Swimming speed of copepod after removal of acrylic plate



9.0±4.5 mm/sec
(n=30, p=0.002)

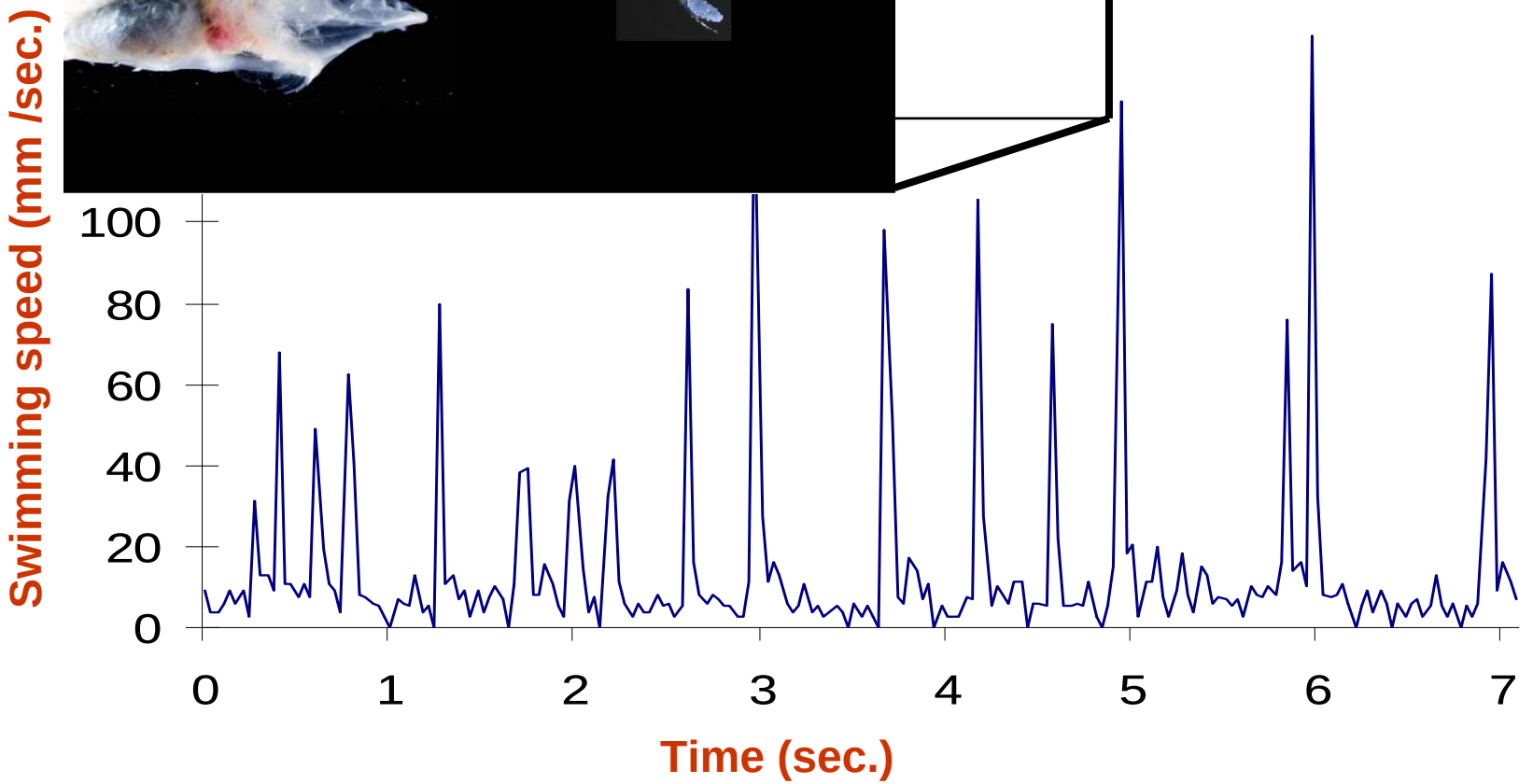
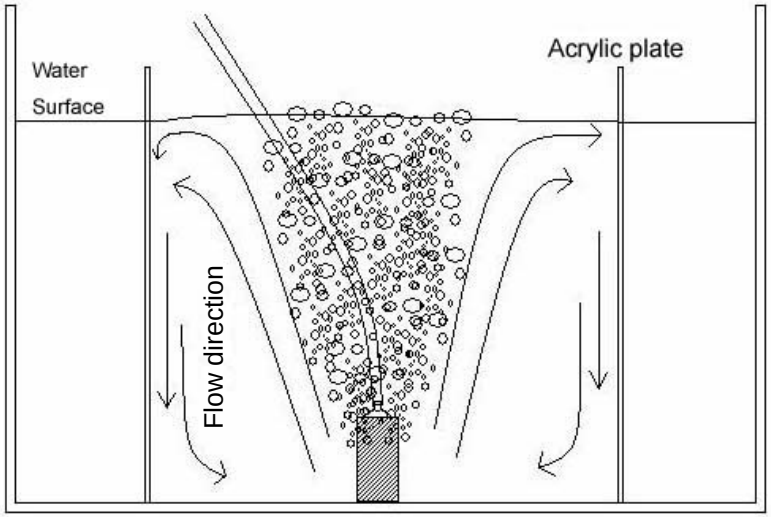
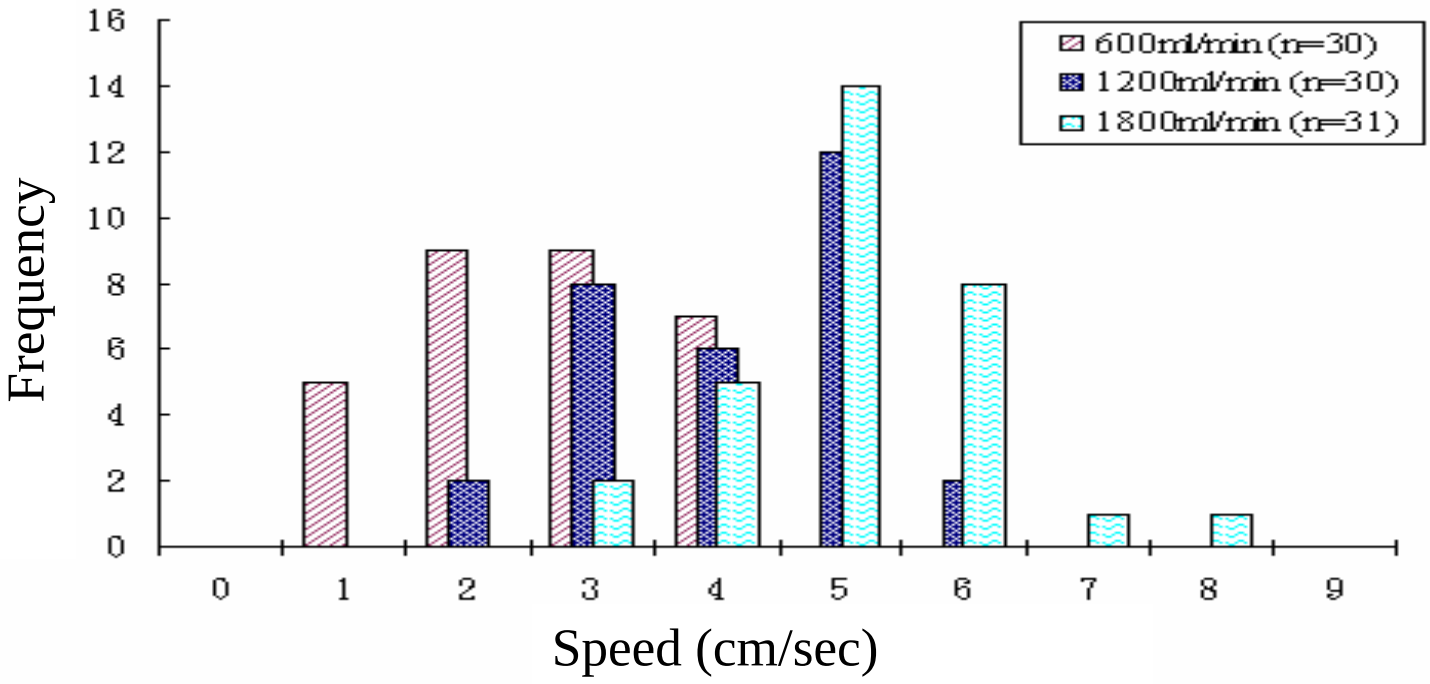


Table 1: Swimming speed **of *P. annandalei* without fish larvae, larvae present in the environment but isolated by a transparent acrylic plate; and in the presence of fish larvae without isolating plate**

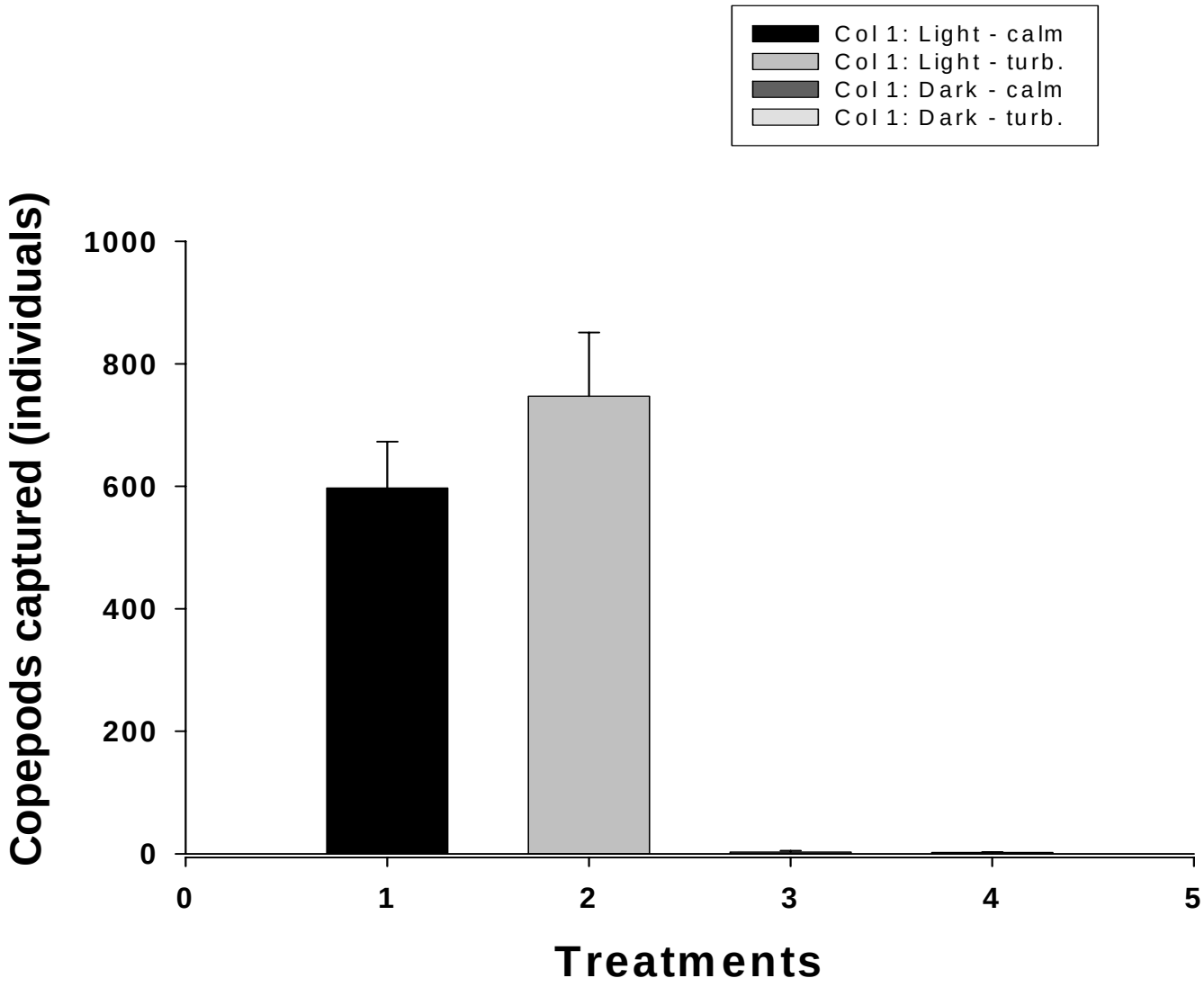
Serial No.	Experimental condition	No. of individuals observed	Swimming speed (mm/s) (mean ± SD)
A	Copepods without fish larvae	30	5.6± 1.5
B	Copepods isolated from fish larvae by acrylic plate	30	5.5±1.6
C	Copepods exposed to fish larvae	30	9.0±4.5
Statistical significance A+B *vs* C (one way ANOVA; p=0.002**			

Particle motion in relation to air bubbling frequency





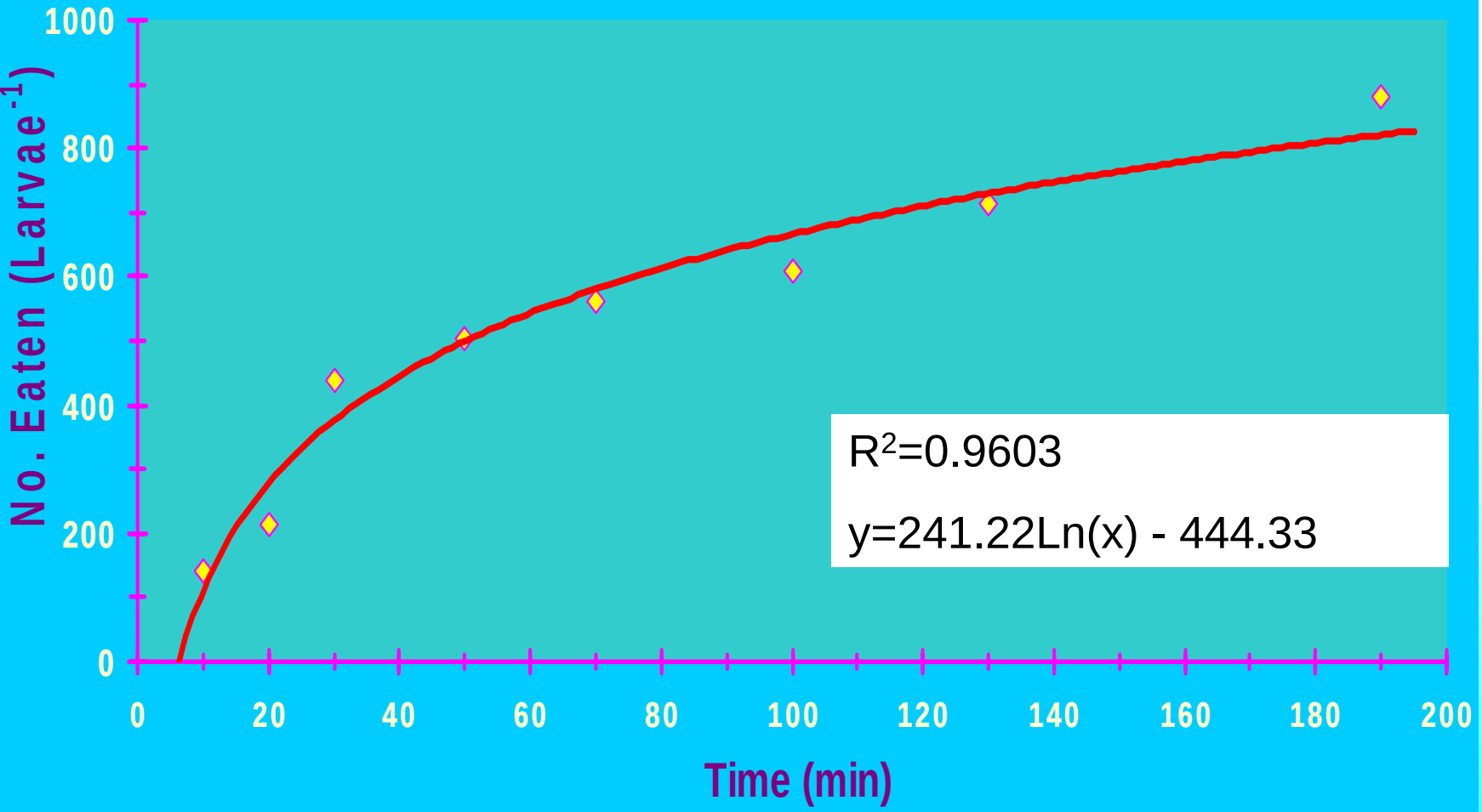
Predation success under light *vs.* dark and calm *vs.* moderate turbulent conditions



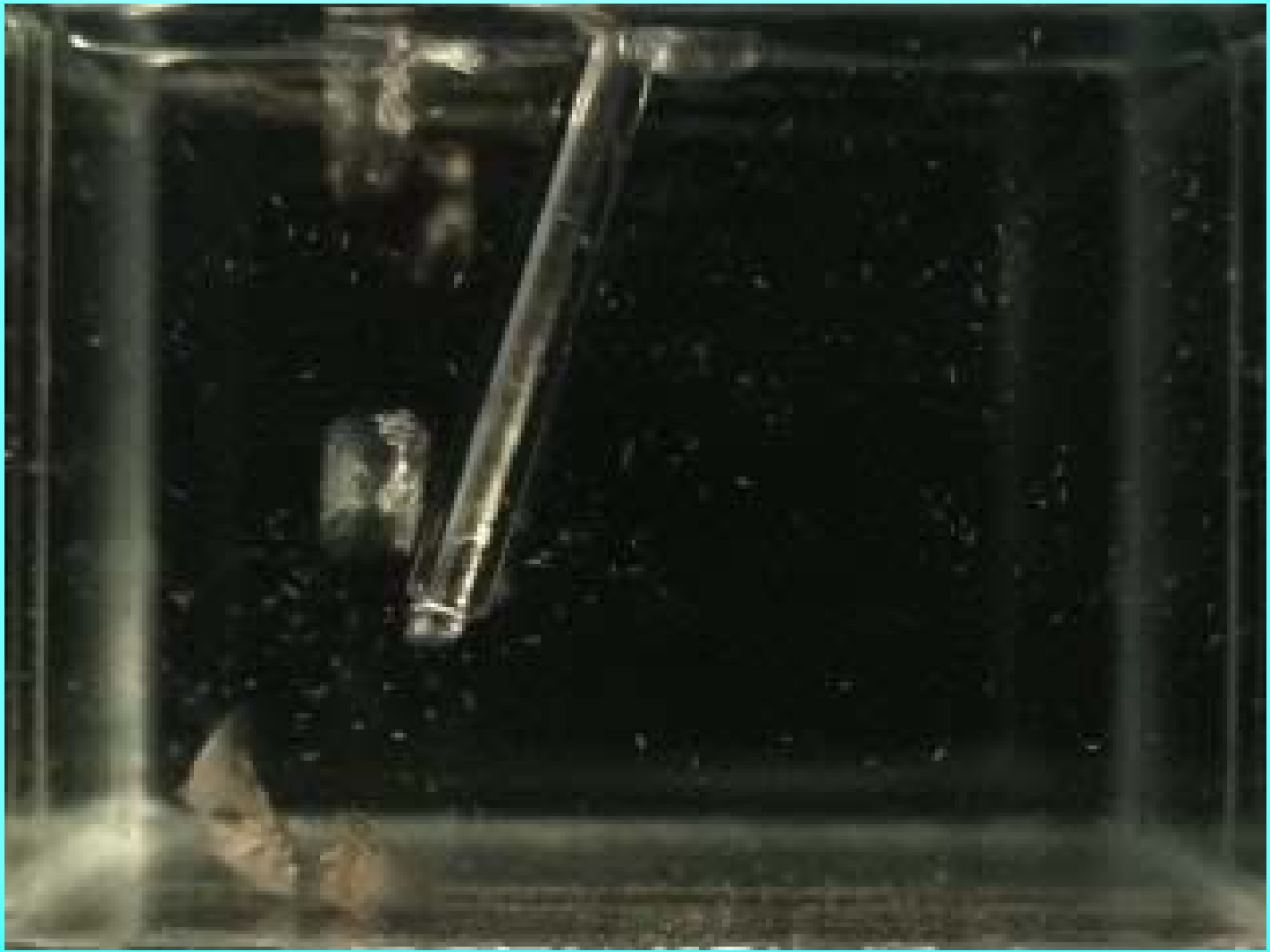
Predation by fish on *P. annandalei* at calm water conditions

Escape response of *P. annandalei* at calm water conditions (observation period: 3.83 sec; total distance passed by the copepod: 186.9 mm)

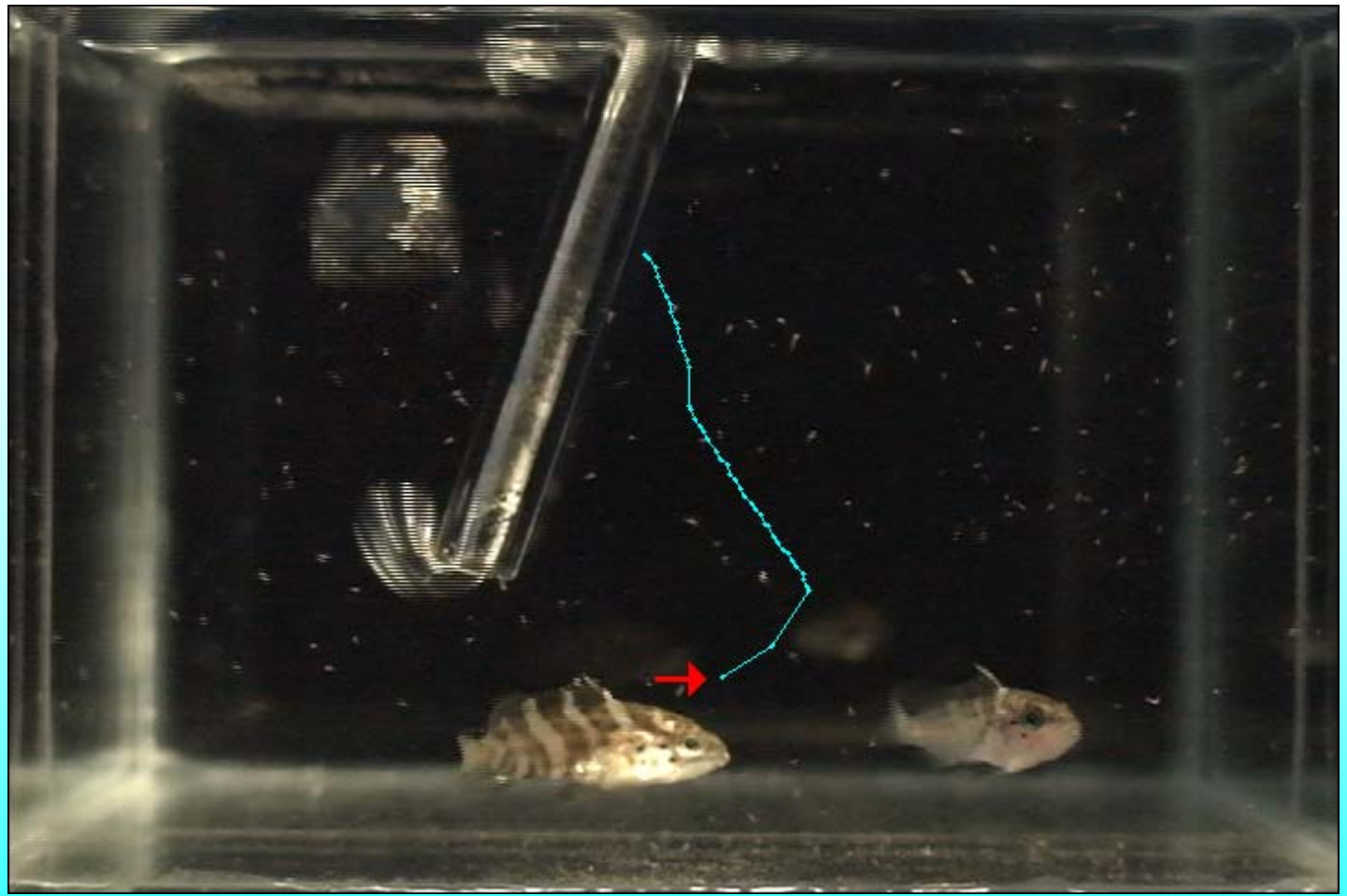
Captured copepod at calm conditions with time (min)

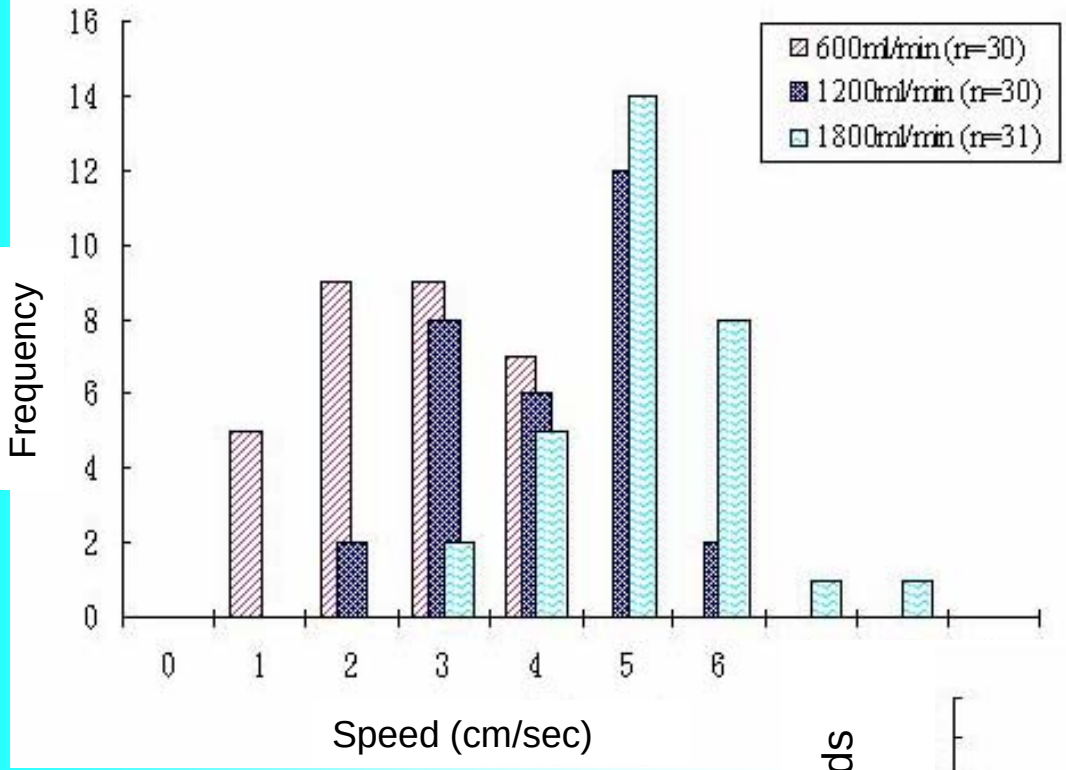


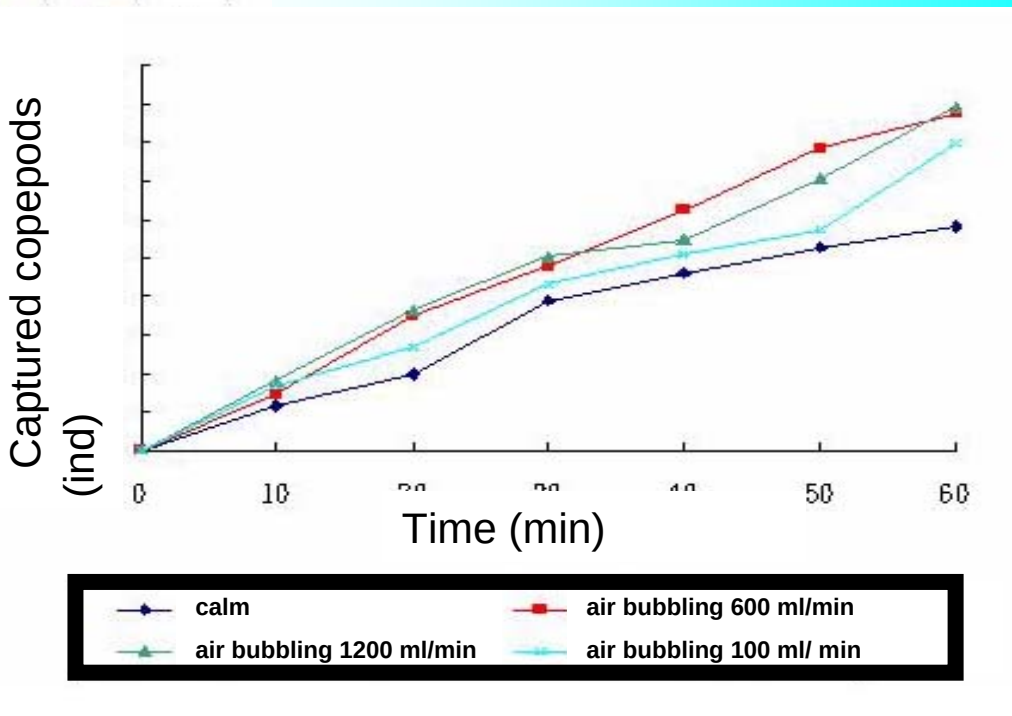
Predation by fish on *P. annandalei* at turbulent conditions



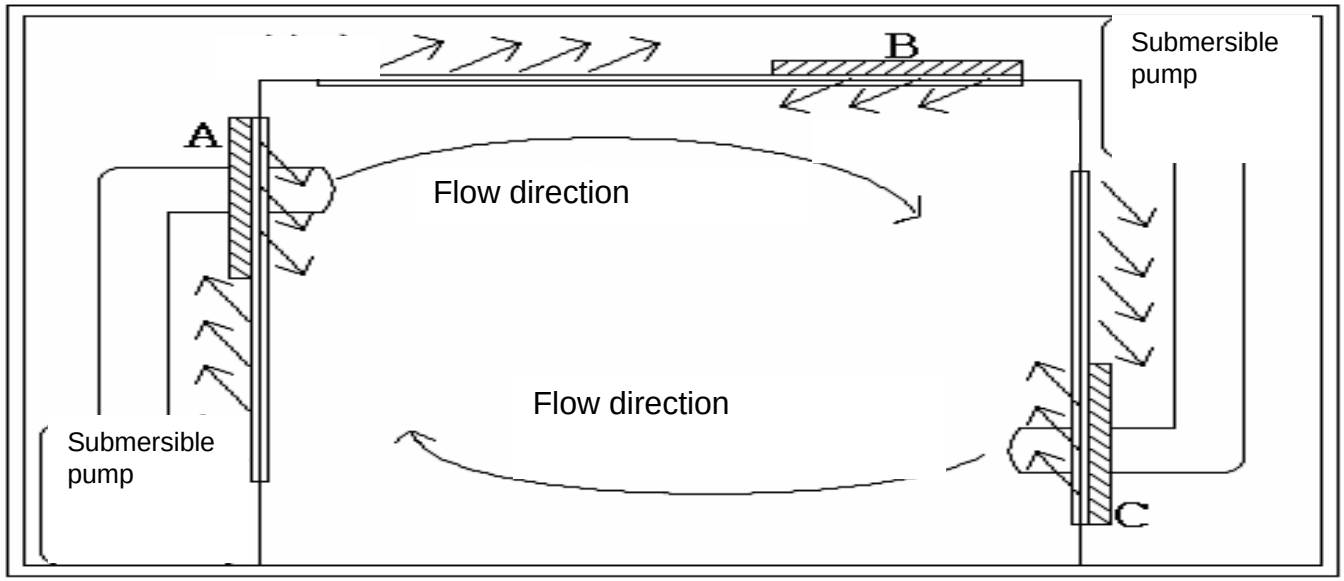
Escape response of *P. annandalei* at turbulent conditions (observation period: 2.86 sec; total distance passed by the copepod: 94.1 mm)

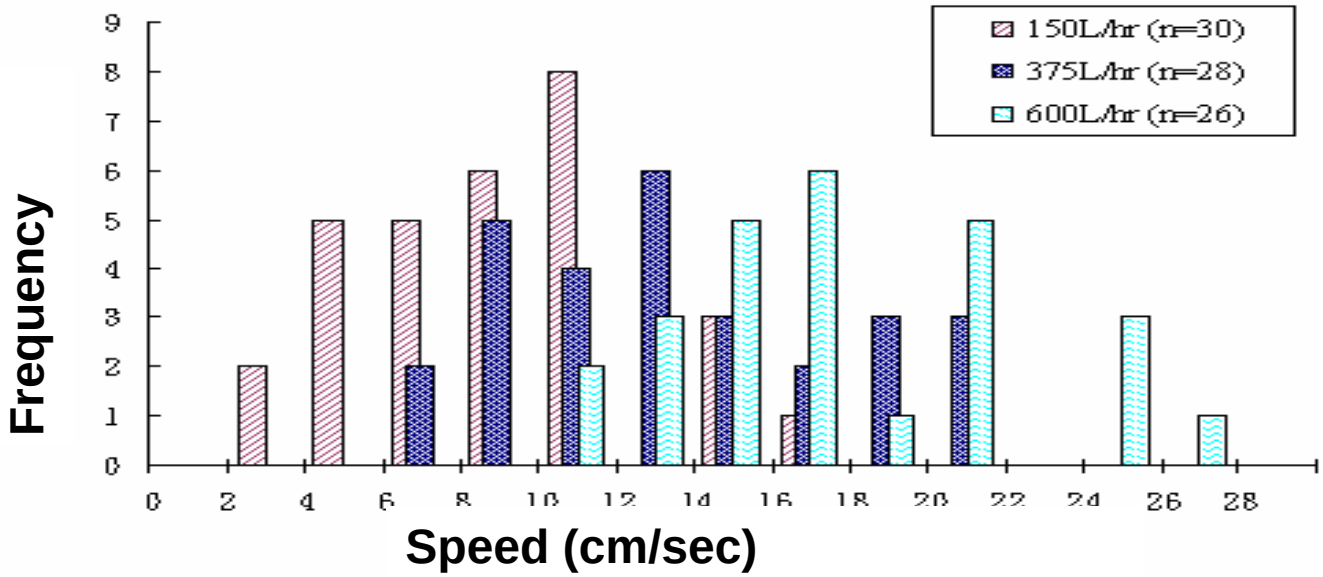



600ml/min (n=30)
1200ml/min (n=30)
1800ml/min (n=31)
Frequency
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
Speed (cm/sec)

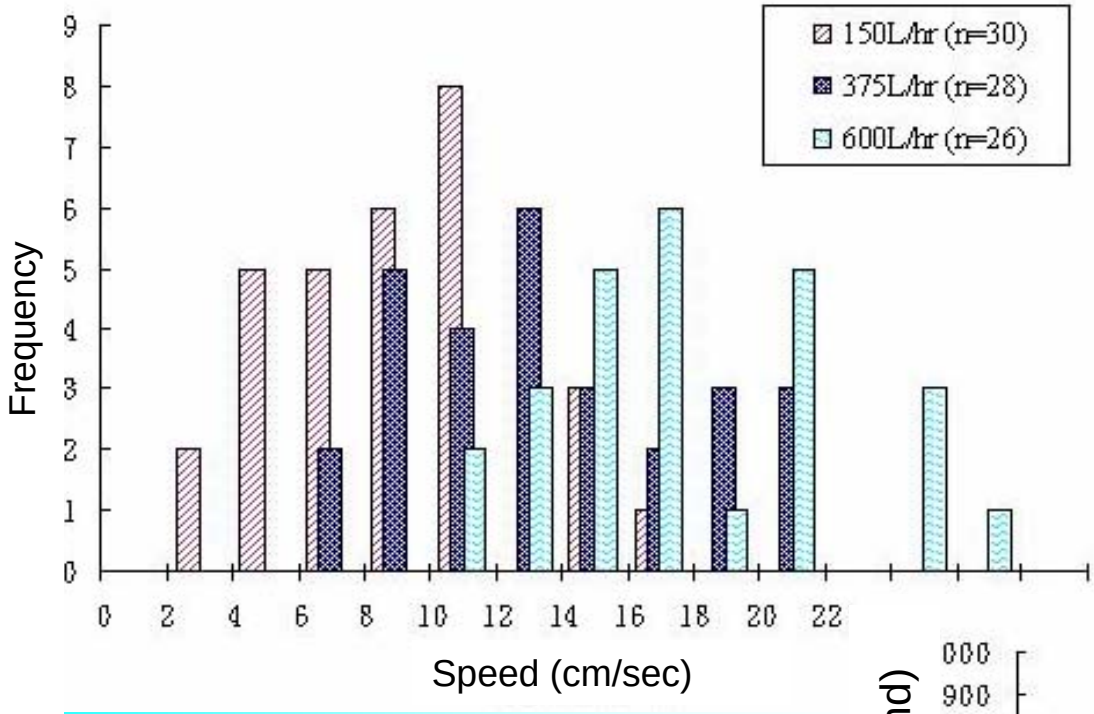

Captured copepods (ind)
0
10
50
60
Time (min)
calm
air bubbling 600 ml/min
air bubbling 1200 ml/min
air bubbling 100 ml/ min

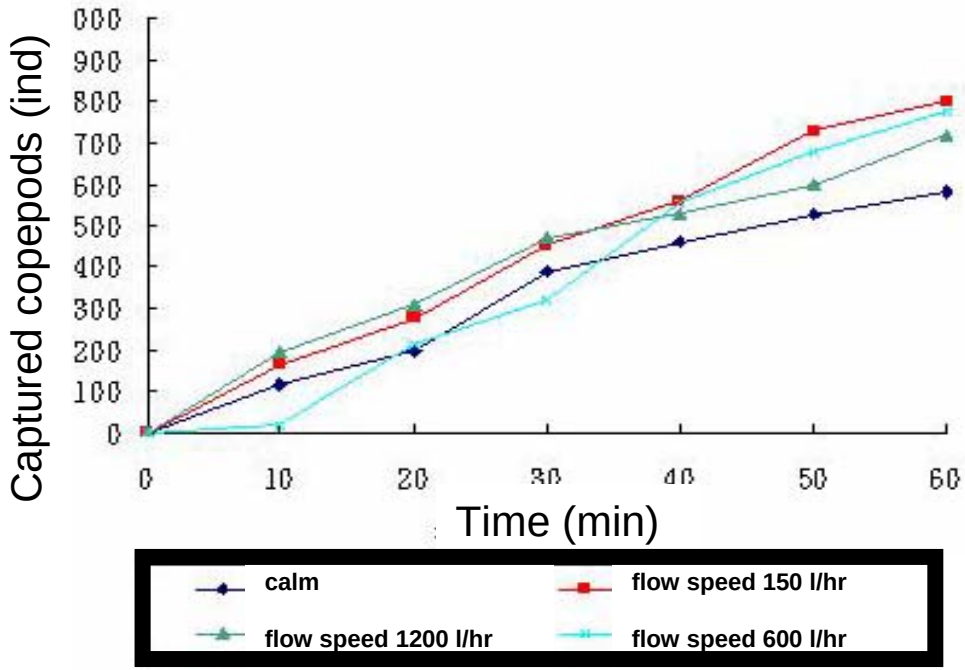
Particle motion in relation to flow



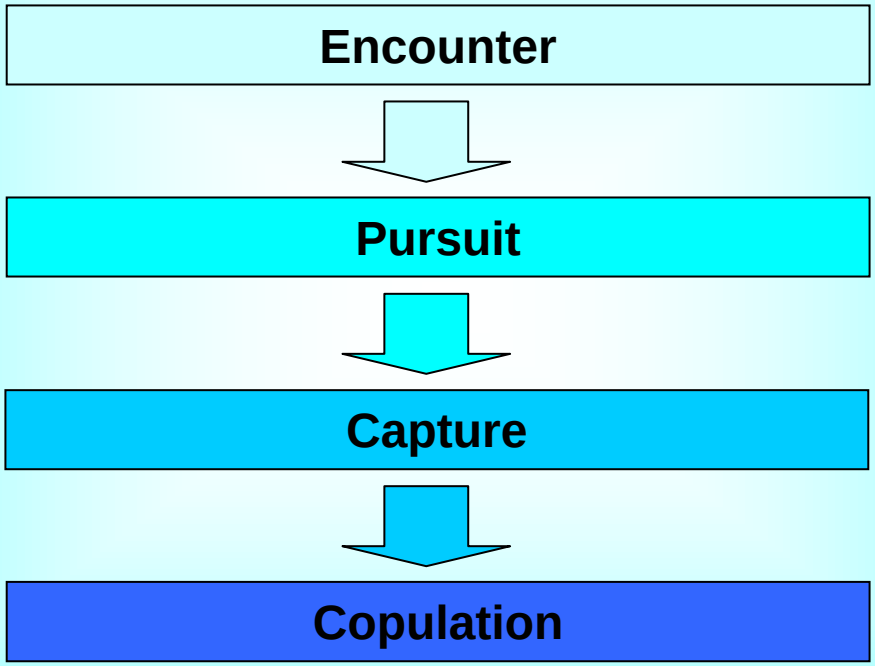


Predation by fish fry on *P. annandalei* at flow conditions (current speed = 600 l hr -1)


150L/hr (n=30)
375L/hr (n=28)
600L/hr (n=26)
Frequency
Speed (cm/sec)

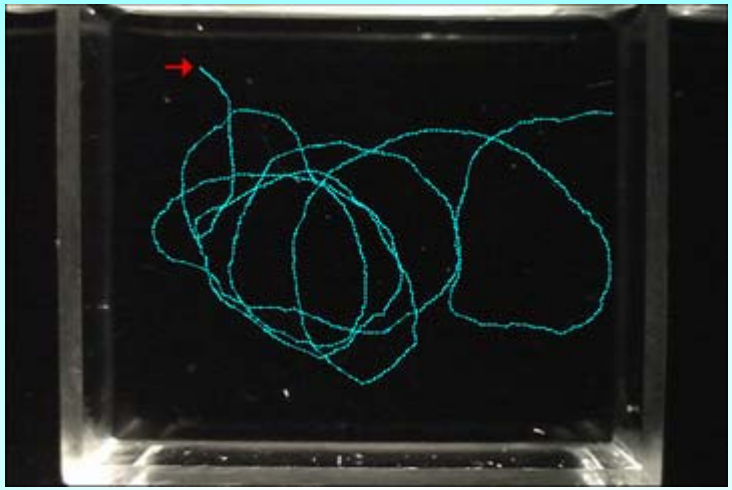

Captured copepods (ind)
Time (min)
calm
flow speed 150 l/hr
flow speed 1200 l/hr
flow speed 600 l/hr

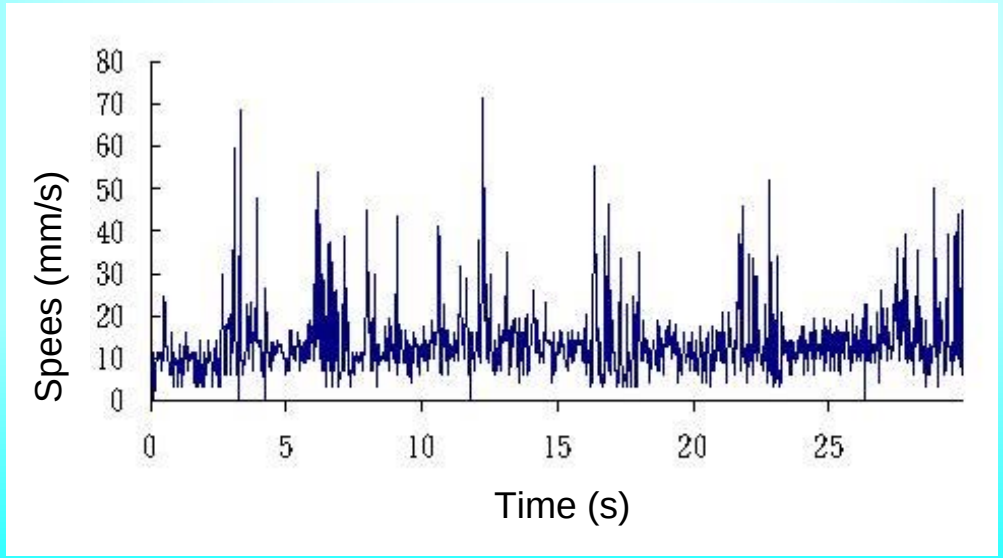
Behavioral sequence during a mating interaction (Buskey 1998):



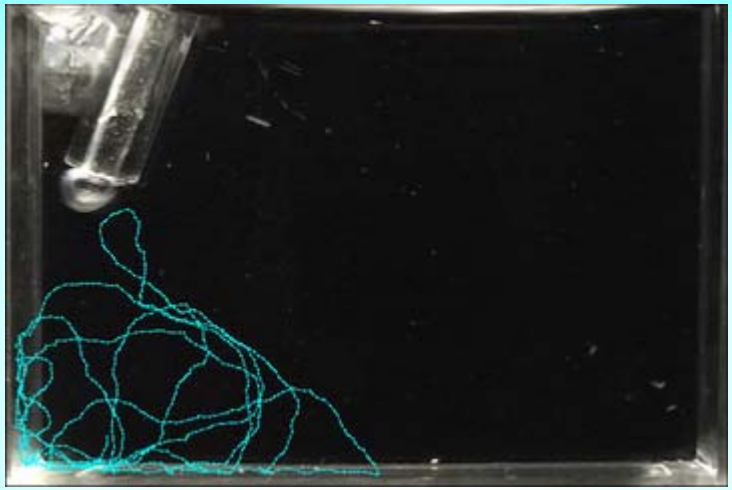
… effect of hydrodynamic conditions?

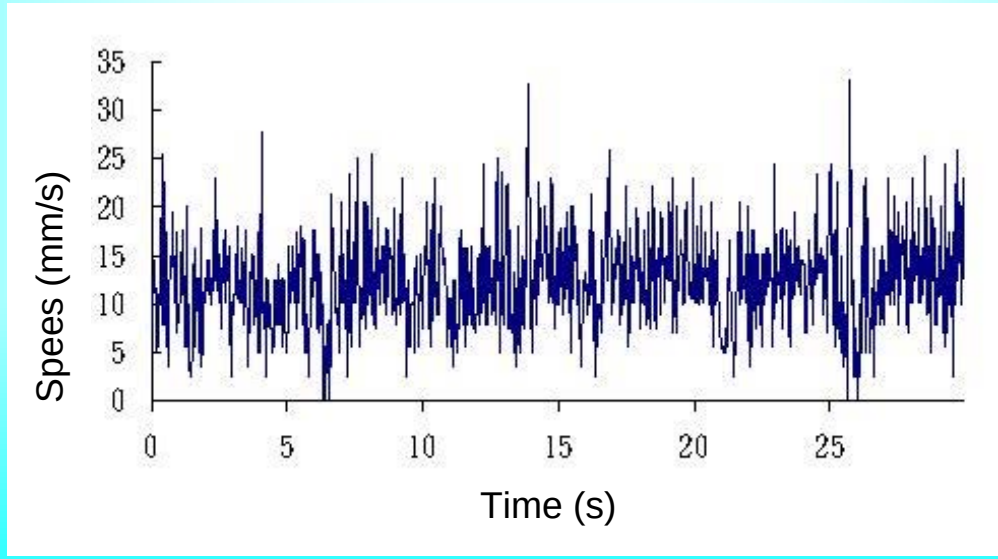
Swimming trajectory of male *P. annandalei* searching for female at calm water conditions and time course of copepod swimming speed (average swimming speed 13.67 mm/s)



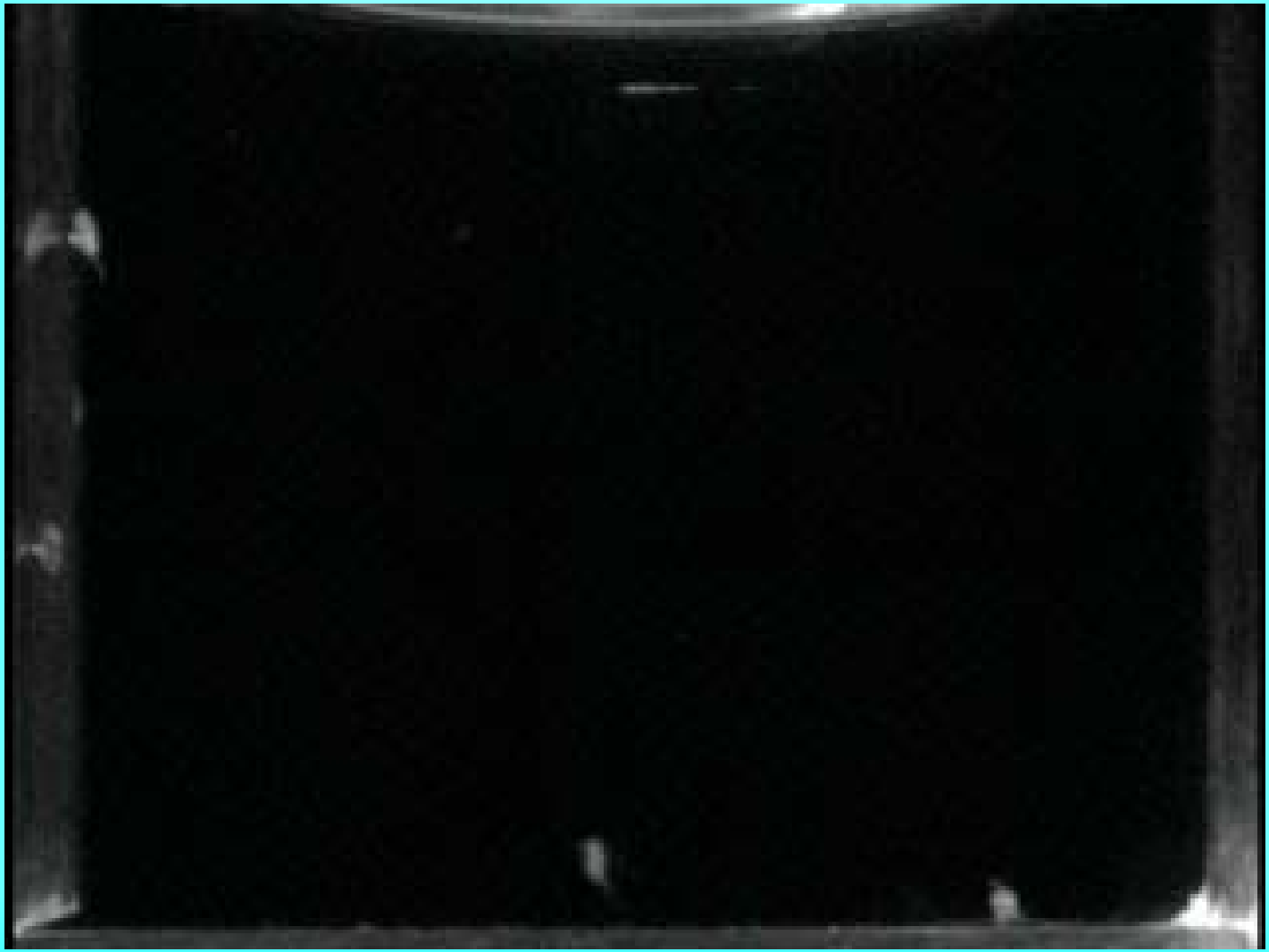


Swimming trajectory of male *P. annandalei* searching for female at moderate turbulent conditions and time course of copepod swimming speed (average swimming speed 12.24 mm/s)





Mating behavior of *P. annandalei* (A)



Close-up of mating behavior of *P. annandalei*

Conclusions

(I) The detection of predators and the subsequent escape response of *P. annandalei* were significantly higher at calm than at turbulent conditions

(II) Fish are able to capture *P. annandalei* only at light conditions and more efficiently at moderately turbulent than at calm conditions

(III) *P. annandalei* is able to mate successfully at calm or at moderately turbulent conditions – no mating was observed at highly turbulent conditions

Thank You!