

1 **Title: Enhanced fast start performance and anti-predator behaviour in a coral reef fish**  
2 **in response to suspended sediment exposure**

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13

14 **Abstract**

15 Declining water quality, in particular elevated suspended sediments, pose a significant threat  
16 to coastal coral reefs. We exposed juvenile anemonefish (*Amphiprion melanopus*) to two  
17 suspended sediment concentrations (0 or 180 mgL<sup>-1</sup>) for 7 days and examined their predator  
18 escape performance and anti-predator behaviour in both clear water and suspended sediments  
19 (0 and 180 mgL<sup>-1</sup>, i.e., acute exposure). After 7-day exposure to suspended sediments, fish  
20 responded faster to a mechanical stimulus and exhibited enhanced fast starts compared to  
21 individuals reared in clear water, regardless of acute exposure. Fish were also less active and  
22 avoided open areas when exposed to elevated suspended sediments in the test arena when  
23 compared to clear water, irrespective of prior 7-day exposure. While these changes are likely  
24 strategies to compensate for an increased perceived predation risk in suspended sediments,  
25 they may also be associated with non-consumptive costs for juveniles living on turbid reefs.

26 *Keywords:* suspended solids, sub-lethal effects, predator-prey interactions, turbidity, fish  
27 health

28

29

## 30 **Introduction**

31           Suspended sediment concentrations in tropical coastal waters have increased  
32 substantially over the past few decades as a result of human activities including agriculture,  
33 dredging, and shipping (Syvitski et al. 2005) and are altering the composition of biological  
34 communities (Fabricius et al. 2005). Elevated levels of suspended sediments can influence  
35 coral reef fish assemblages indirectly through changes in the composition and structural  
36 complexity of benthic habitats (Brown et al. 2017; Hamilton et al. 2017). Recent studies,  
37 however, suggest that suspended sediments may also affect the physiology and behaviour of  
38 reef fishes, which may compound the negative effects of habitat degradation (reviewed in  
39 Wenger et al. 2017).

40           Elevated suspended sediments reduce visual acuity and can thereby influence  
41 important ecological processes such as predator-prey interactions (Wenger et al. 2017).  
42 Reduced visual acuity can delay the detection of approaching predators, potentially altering  
43 predation rates (Meager et al. 2006). While the early detection of predators is crucial, the  
44 ability to escape a predator attack is equally important for prey survival (McCormick et al.  
45 2018; Walker et al. 2005). Most prey fish escape predatory attacks via fast starts, i.e., short,  
46 high-energy swimming bursts elicited by a sudden stimulus (Domenici and Blake 1997).  
47 Prolonged exposure to elevated suspended sediments, however, has been shown to reduce the  
48 aerobic scope (i.e., the capacity for aerobic activities) of some reef fishes (Hess et al. 2017);  
49 this may compromise their capacity to engage in or recover from energetically costly  
50 activities such as fast starts (Killen et al. 2015). Yet, the effects of suspended sediments on  
51 the fast start performance of reef fishes are unknown.

52           A reduced ability to detect predators may decrease prey survival (Meager et al.  
53 2006), and, as a consequence, may increase the perceived risk of predation in suspended

54 sediments. Fish commonly respond to increases in predation risk with strategic changes in  
55 anti-predator behaviour or fast start performance (Domenici 2010; Lima 1998; Ramasamy et  
56 al. 2015). Such changes can be linked to considerable non-consumptive costs (Hawlena and  
57 Schmitz 2010; Preisser et al. 2005). For example, enhanced vigilance is associated with  
58 increased metabolic costs and can trade-off with foraging (Lima 1998; Killen et al. 2015;  
59 Preisser et al. 2005). Non-consumptive costs can result in reduced growth and condition  
60 (Hawlena and Schmitz 2010; Lima 1998) and can have equal or greater effects on prey  
61 population dynamics than predation itself (Preisser et al. 2005). Non-consumptive costs are  
62 particularly important to consider for juvenile reef fishes, as survivorship is typically low  
63 during this critical life-history stage and has been related to the growth and condition of  
64 individuals (Hoey and McCormick 2004). Despite its potential importance in shaping  
65 juvenile - and hence adult - populations, our understanding of the effects of suspended  
66 sediments on perceived predation risk and associated changes in performance or anti-predator  
67 behaviour of juvenile reef fishes is limited.

68         The aim of this study was to test the effects of suspended sediments on the fast start  
69 performance and anti-predator behaviour of a common coral reef fish. Specifically, we  
70 exposed juvenile cinnamon clownfish (*Amphiprion melanopus*) to suspended sediments for 7  
71 days (0 or 180 mgL<sup>-1</sup>) and examined their fast start performance and anti-predator behaviour  
72 in both 0 and 180 mgL<sup>-1</sup> (i.e., after 5 min habituation time, referred to as “acute exposure”  
73 hereafter) suspended sediment concentrations. Exposing fish to suspended sediments both  
74 acutely and for 7 days allowed us to distinguish between potential effects on fast starts and  
75 anti-predator behaviour as a result of turbidity (e.g., sensory impairment) and potential effects  
76 driven by physiological changes such as reduced aerobic scope following prolonged exposure  
77 to suspended sediments.

78

79 **Materials and methods**

80 *Suspended sediment exposure*

81 *Amphiprion melanopus* larvae were sourced from five captive breeding pairs  
82 maintained at  $28.5 \pm 0.5^\circ\text{C}$  and reared following standard protocols (electronic supplemental  
83 material, ESM). At 35-days post-hatch, juveniles were exposed to 0 or  $180 \text{ mgL}^{-1}$  of  
84 Australian bentonite ( $0.7 \pm 0.5$  or  $30.0 \pm 4$  NTU, respectively) for 7 days. Bentonite clay is  
85 representative of suspended sediments common to the Great Barrier Reef (GBR). The  
86 sediment concentration and exposure duration were selected to represent conditions  
87 frequently observed on inshore reefs of the GBR (Larcombe et al. 2001; Wenger et al. 2016).  
88 Sediments were maintained in suspension using a series of pumps in external sumps (ESM).

89  
90 *Fast start performance and anti-predator behaviour*

91 After 7-day exposure, juvenile *A. melanopus* ( $18.7 \pm 2.1$  mm standard length; mean  
92  $\pm$  SE) were introduced into a circular (21 cm diameter) test arena contained within an  
93 aquarium (ESM). The base of the arena was transparent, allowing the position of the  
94 juveniles to be recorded as a silhouette via a mirror positioned at an angle of  $45^\circ$  below the  
95 arena (Fig. S1). Juveniles were left undisturbed for five minutes, after which their behaviour  
96 was recorded for two minutes (Casio ex-fh20 camera). Following this, individuals were  
97 startled by a mechanical stimulus (a small weight), which was positioned above the arena and  
98 released via an electromagnet (following Allan et al. 2014). Responses of fish were recorded  
99 at  $480 \text{ frames second}^{-1}$ . Each individual was tested twice, i.e. both in 0 and  $180 \text{ mgL}^{-1}$   
100 suspended sediments in the arena (Fig. S2), and the presentation order of these trials was  
101 randomized. In between the two trials, fish were housed in individual aquaria for 1.5 hours to  
102 recover from escape responses.

103 *Analysis of videos*

104 Videos were analyzed in ImageJ (Version 1.48, National Institute of Health, USA)  
105 using a manual tracking plug-in. To determine fast start performance, the following variables  
106 were measured: 1) response latency, 2) turning rate, 3) maximum acceleration, 4) maximum  
107 escape speed, 5) average escape speed, 6) distance travelled (see ESM for more details).  
108 Variables 3 – 6 were measured within the first 41 ms of the response, i.e. during the first two  
109 caudal fin flips (Domenici and Blake 1997).

110 To determine anti-predator behaviour, the position of individuals within the arena  
111 was determined every three seconds from the videos of the initial 2-min observation period.  
112 These data were used to derive the total distance moved by individuals (as a proxy for  
113 activity) and the percent of time they spent within 2.5 body lengths of the wall of the arena  
114 (i.e., thigmotaxis/avoidance of open areas; Schnörr et al. 2012) (ESM).

115

116 *Statistical analyses*

117 Generalized linear mixed models were used to analyze the effects of acute and 7-day  
118 exposure to suspended sediments and their interaction on fast starts, activity, and thigmotaxis  
119 of juveniles in R (v.3.3.2) using the package lme4 (Bates et al. 2015). Fish standard length  
120 and distance between fish and the stimulus were mean-centered and included as covariates,  
121 and presentation order of trials and fish identity were included as random factors (ESM).  
122 Significance of fixed effects was evaluated via model comparison.

123

## 124 Results and Discussion

125 After 7-day exposure to elevated suspended sediments (180 mgL<sup>-1</sup>), juvenile *A.*  
126 *melanopus* were faster to respond to the stimulus (11.3 ± 1.2 ms vs 14.2 ± 1.0 ms, mean ±  
127 SE; n = 65,  $\chi^2(1) = 5.36$ ,  $p = 0.02$ , Fig. 1a), exhibited higher turning rates (10.2 ± 0.3 deg ms<sup>-1</sup>  
128 vs 9.2 ± 0.3 deg ms<sup>-1</sup>,  $\chi^2(1) = 4.26$ ,  $p = 0.03$ , Fig. 1b), higher average escape speeds (72.1 ±  
129 3.5 cm sec<sup>-1</sup> vs 62.7 ± 3.4 cm sec<sup>-1</sup>;  $\chi^2(1) = 6.38$ ,  $p = 0.01$ , Fig. 1c), and moved further away  
130 from the stimulus within the first 41 ms of the simulated attack (34.4 ± 1.6 mm vs 29.5 ± 1.5  
131 mm,  $\chi^2(1) = 6.51$ ,  $p = 0.01$ , Fig. 1d) than fish exposed to clear water (0 mgL<sup>-1</sup> suspended  
132 sediments) for 7 days. Maximum escape speeds and maximum acceleration were not  
133 influenced by 7-day exposure to suspended sediments (Fig. 1e and f, see ESM for details).  
134 Maximum acceleration, however, was influenced by acute exposure to suspended sediments,  
135 with fish achieving higher maximum acceleration (40.8 ± 2.3 cm sec<sup>-2</sup> vs 36.8 ± 2.0 cm sec<sup>-2</sup>,  
136  $\chi^2(1) = 5.2$ ,  $p = 0.02$ , Fig. 1f) when the water in the test arena was turbid as opposed to when  
137 it was clear. Acute exposure to suspended sediments did not influence any other fast start trait  
138 (ESM). The shorter response latencies suggest that fish were more vigilant after 7-day  
139 exposure to suspended sediments, and coupled with the higher escape speeds, turning rates,  
140 and acceleration, these changes would be expected to increase chances of a fish to survive a  
141 predator attack (Domenici and Blake 1997; Walker et al. 2005).

142 Acute exposure to suspended sediments led to changes in anti-predator behavior of  
143 juvenile *A. melanopus*. Fish moved significantly less (38.6 ± 4.8 cm vs 51.8 ± 4.8 cm; n = 78,  
144  $\chi^2(1) = 13.47$ ,  $p = 0.0002$ , Fig. 2a) and spent less time in the open area of the arena (i.e.,  
145 enhanced thigmotaxis) (11.6 ± 2.4 % vs 28.2 ± 3.5 %;  $\chi^2(1) = 11.16$ ,  $p = 0.0008$ , Fig. 2b)  
146 when exposed to suspended sediment in the arena compared to clear water. Fish exhibited  
147 these changes regardless of whether they were previously exposed to suspended sediments or

148 clear water for 7 days (ESM). Exposure for 7-days would be expected to be sufficient for fish  
149 to habituate to suspended sediments, suggesting that the observed changes in behaviour (and  
150 fast start performance) are not short-term reactions to a novel threat (i.e., turbidity), but rather  
151 adjustments to changes in the environment. Juvenile *A. melanopus* are commonly found on  
152 turbid inshore reefs (Fautin 1992), where turbidity levels can be variable. Short periods  
153 (minutes to hours) of elevated suspended sediments are caused by resuspension from waves  
154 and currents (Larcombe et al. 2001), while periodic events such as flood plumes can increase  
155 suspended sediment concentrations for days or weeks at a time (Wenger et al. 2016).  
156 Reductions in activity and enhanced thigmotaxis are strategies to decrease the likelihood of  
157 predator interactions (Lima 1998), suggesting that juvenile *A. melanopus* may adopt more  
158 cautious behavior when suspended sediment levels are high.

159         Contrary to expectations, neither 7-day nor acute exposure to suspended sediments  
160 had negative effects on the fast start performance of fish. Exposure to suspended sediments  
161 for 7 days was found to compromise the aerobic performance of juvenile *A. melanopus* (Hess  
162 et al. 2017), yet the locomotor performance of fish in the present study was enhanced rather  
163 than constrained. Similarly, acute exposure to suspended sediments did not influence the  
164 ability of fish to detect a stimulus that was a short distance away (~5cm), simulating an  
165 ambush attack. This distance may have not been sufficient for suspended sediments to  
166 significantly reduce visual cues. Alternatively, fish may have used sound and/or water  
167 displacement, in addition to visual cues, to detect the stimulus. It is well established,  
168 however, that suspended sediments delay the visual detection of predators (Wenger et al.  
169 2017) and attenuate sound transmission over longer distances (Brown et al. 1998). The  
170 observed enhanced fast starts and anti-predator behaviour following suspended sediment  
171 exposure are typical responses to increases in perceived predation risk (Domenici 2010; Lima  
172 1998) and were likely an attempt to compensate for this reduced ability to detect visual

173 and/or auditory cues associated with predators. Supporting this, a closely related species,  
174 *Acanthochromis polyacanthus*, has been found to enhance their anti-predator response to  
175 olfactory cues in suspended sediments to compensate for reduced visual cues (Leahy et al.  
176 2011).

177 Whether the enhanced fast start performance and antipredator behaviour would  
178 translate into changes in predation rates in suspended sediments compared to clear water is  
179 not known, since suspended sediments may also affect the detection of prey by predators (e.g.  
180 Higham et al. 2015). A study on newly settled *Chromis atripectoralis* preyed upon by an  
181 ambush predator, *Pseudochromis fuscus*, documented that suspended sediments indeed  
182 influenced predation rates, with increased predation at medium (30 mgL<sup>-1</sup>) suspended  
183 sediment levels, compared to low predation rates at both lower or higher levels of suspended  
184 sediment (Wenger et al. 2013).

185 Enhanced fast starts and anti-predator behaviour, as observed in response to  
186 suspended sediments, may lead to non-consumptive costs (Preisser et al. 2005). While *A.*  
187 *melanopus* lives symbiotically with sea anemones (Fautin and Allen 1992), the area they use  
188 for foraging (i.e., their home range) extends considerably beyond the area covered by their  
189 host (Ross 1978). Juveniles also frequently migrate between sea-anemones (Ross 1978).  
190 More cautious behaviour, such as we observed in elevated suspended sediments, may not  
191 only reduce movement within their home range, potentially limiting access to food, but may  
192 also reduce the ability of juveniles to find a suitable anemone. Indeed, another damselfish  
193 species, *Pomacentrus moluccensis*, has been found to reduce movement between settlement  
194 habitats in elevated suspended sediments (Wenger and McCormick 2013). Furthermore, an  
195 increase in perceived predation risk itself is associated with numerous negative effects, such  
196 as impaired growth efficiency and immunocompetence (Hawlana and Schmitz 2010). While  
197 no studies, to date, have examined the metabolic costs of enhanced locomotor performance



198 during fast starts, shorter response latencies have been linked to non-consumptive costs.  
199 Shorter response latencies are a result of enhanced vigilance, which is associated with  
200 increased metabolic costs (Killen et al. 2015) and is well known to trade-off with feeding in  
201 fish (Godin and Smith 1988; Preisser et al. 2005). Thus, while the enhanced fast start  
202 performance and anti-predator behaviours can be perceived as beneficial when suspended  
203 sediment concentrations are high, such changes are likely associated with considerable costs  
204 for *A. melanopus* juveniles living on turbid reefs.

205

206 **Fig. 1** Variables associated with fast starts of juvenile *Amphiprion melanopus* exposed to 0 or  
207 180 mgL<sup>-1</sup> suspended sediments for 7 days and tested in both clear (closed circles) and turbid  
208 water (open circles), i.e. “acute exposure” (effect plots and associated adjusted means ± SE).  
209 A) Latency to respond to a stimulus, b) turning rate, c) average escape speed, d) distance  
210 escaped within 41 ms of the response, e) maximum escape speed, and f) maximum  
211 acceleration.

212 **Fig. 2** Anti-predator behaviour of juvenile *A. melanopus* exposed to 0 or 180 mgL<sup>-1</sup>  
213 suspended sediments for 7 days and tested in both clear (closed circles) and turbid water  
214 (open circles), i.e. “acute exposure” (effect plots and associated adjusted means ± SE). A)  
215 Percent of time spent > 2.5 body lengths away from the wall of the arena, and b) total  
216 distance moved during the 2 min trial.

217

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220

## 221 **Data accessibility**

222 <https://cloudstor.aarnet.edu.au/plus/index.php/s/TUAtZEXLUJ2ZshL>

223

## 224 **Conflict of interest statement**

225 On behalf of all authors, the corresponding author states that there is no conflict of interest.

## 226 **Ethics statement**

227 This research has been conducted according to the Australian code for the care and use of animals for  
228 scientific purposes and has been approved by the Animal Ethics Committee at James Cook University  
229 (animal ethics approval number A2218).

230

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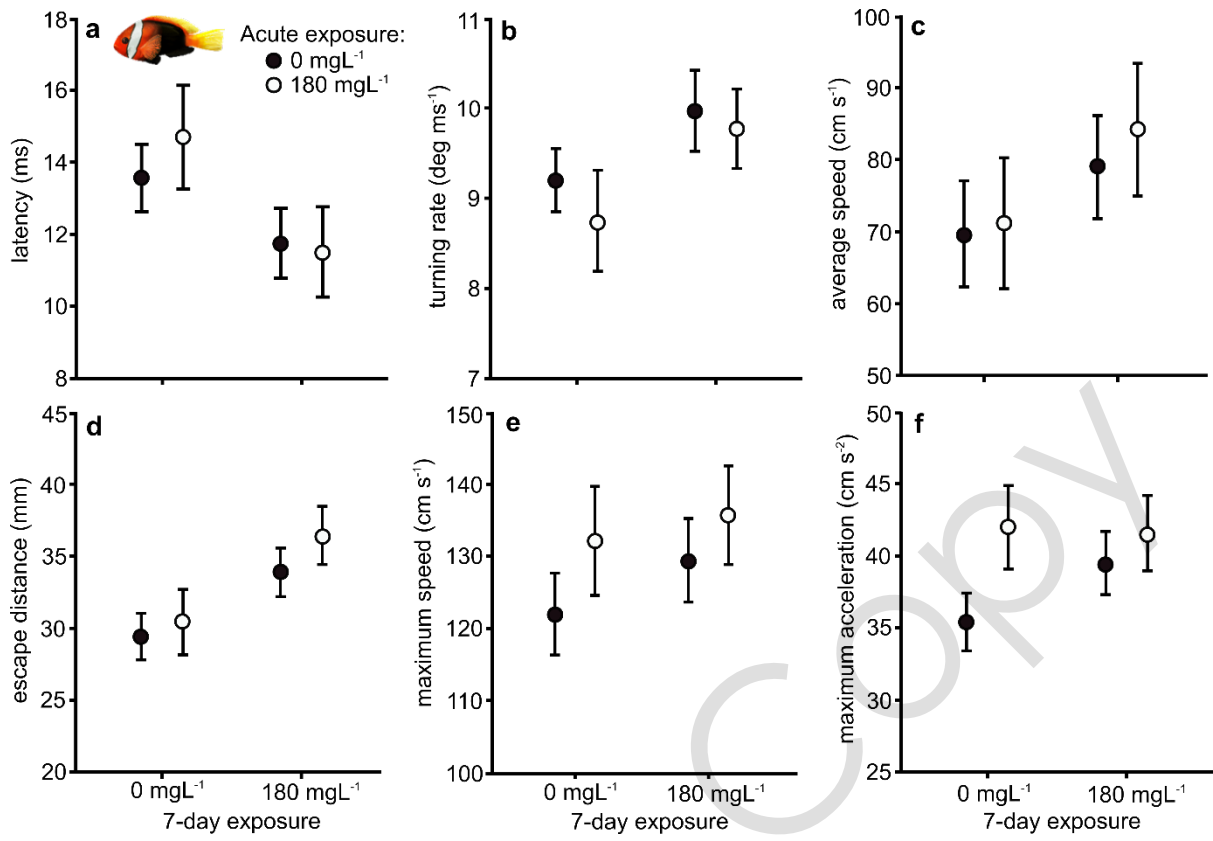
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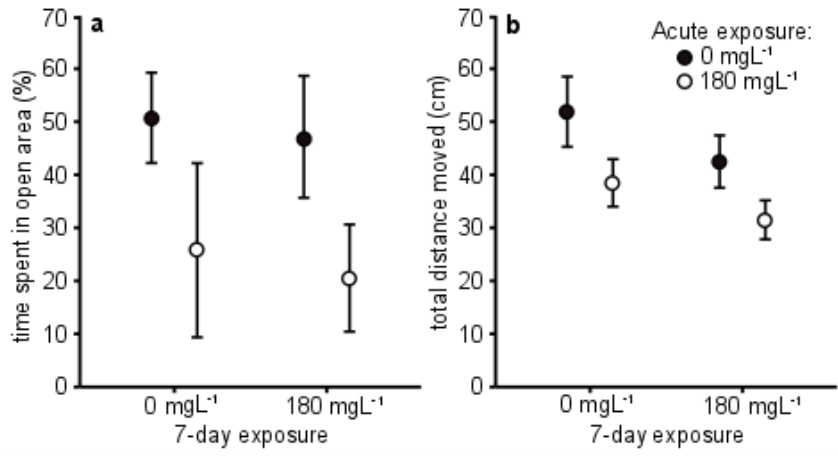
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338 **Figure 1**

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**Figure 2**

## 352 **Supplementary methods**

### 353 *Suspended sediment exposure*

354 Sediment was suspended in external 200 L sumps fitted with submersible pumps.  
355 Each sump delivered water at a rate of  $210 \pm 30 \text{ mL min}^{-1}$  to the bottom of 18 replicate  
356 conical experimental aquaria (3L). The water drained through an overflow outlet at the top of  
357 the experimental aquaria back into sumps. Water temperature was maintained at  $28.5 \pm 0.5^\circ\text{C}$   
358 via 1000 W heaters (Eheim GmbH & Co. KG, Deizisau, Germany) in each sump. Sumps were  
359 flushed daily for 1 hour ( $> 100\%$  water exchange) to remove sediment and waste, after  
360 which new sediment (Australian Bentonite) was added to the sumps. Temperature was  
361 monitored daily and turbidity was monitored every four days (WP88 turbidity meter, Thermo  
362 Fisher Scientific, QLD, Australia) throughout the experiments.

363

### 364 *Larval rearing and exposure to experiments*

365 Breeding pairs of *Amphiprion melanopus* laid eggs on terracotta pots, which were  
366 transferred to individual, black painted 40L hatching aquaria on the day hatching was  
367 predicted (i.e. 6 – 8 days after egg deposition, Gordon et al. 2002). Aquaria were kept in a  
368 1000L water bath to maintain temperature at  $28.5 \pm 0.5^\circ\text{C}$  and were flushed every morning  
369 (prior to lights turning on) with filtered seawater for an hour to remove waste. To reduce  
370 glare, algal paste (*Nannochloropsis* spp.) (ProAqua Pty Ltd, QLD, Australia) was added to  
371 the water until the bottom of the aquaria was no longer visible. *Branchionus* spp. rotifers  
372 were added at a density of  $15 \text{ rotifers ml}^{-1}$  until 5 days post-hatch and were then reduced to a  
373 density of  $5 \text{ rotifers ml}^{-1}$  until day 8 post-hatch. Starting at day 5 post-hatch, *Artemia* spp.  
374 nauplii were added to aquaria at a density of  $1 \text{ nauplii ml}^{-1}$  twice daily until day 14 post-  
375 hatch, at which point larvae were fed flakes NRD 0.5 – 0.8 mm (Pro Aqua Pty Ltd) twice  
376 daily. Most fish settled at approximately 8 days post-hatch.

377 At 35 days post-hatch juveniles were randomly assigned to experimental aquaria at a  
378 density of 5 individuals per aquaria. Trials were run sequentially until a total number of 60  
379 individuals per treatment was reached.

380

### 381 *Fast starts*

382 The following variables were measured:

383 Response latency was defined as the time interval between the weight entering the  
384 water and the first movement of the individual.

385 Turning rate was defined as the ratio of stage 1 angle and stage 1 duration (Domenici  
386 et al. 2008). Stage 1 angle was defined as the angle between the position of the fish (i.e. a line  
387 was drawn connecting the center of mass and the tip of the head) prior to the first detectable  
388 movement and at the end of stage 1. The end of stage 1 was reached when the turning rate of  
389 the fish reached zero for the first time (i.e., before a change in the direction of head rotation  
390 occurred).

391 The remaining variables were determined based on stages 1 and 2 of the escape  
392 response (i.e., the first two axial bends, Domenici and Blake 1997), which lasted 41 ms in  
393 this species. The position of the fish was determined for every frame (corresponding to a time  
394 period of 2 ms between two frames) throughout the escape response. The distance moved and  
395 speed was calculated for each pair of consecutive frames. Acceleration was calculated as the  
396 change in speed over time. Based on these measurements, the escape distance (i.e., sum of  
397 distances moved within 41 ms), average and maximum escape speed, and maximum  
398 acceleration were determined.

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#### 401 *Thigmotaxis*

402 Thigmotaxis, or “wall hugging” is a proxy for the shyness of an individual in a novel  
403 environment (Schnörr et al. 2012). As suggested by Schnörr et al. (2012), we used the  
404 proportion of time an individual spent within 2.5 body lengths from the wall to determine  
405 thigmotaxis.

406

#### 407 *Distance to the stimulus*

408 When suspended sediments were present in the test arena, fish were on average  
409 further away from the stimulus ( $5.3 \pm 1.4$  cm) when it entered the water than when the water  
410 was clear ( $4.2 \pm 1.1$  cm) ( $n = 65$ ,  $\chi^2(1) = 14.72$ ,  $p = 0.001$ ), irrespective of 7-day exposure to  
411 suspended sediments ( $\chi^2(1) = 0.02$ ,  $p = 0.89$ ). To test whether distance to the stimulus had an  
412 effect on fast start variables, we initially included distance to the stimulus as covariate in



413 models. However, distance to the stimulus did not have a significant effect on any of the  
414 variables, i.e. response latency,  $n = 65$ ,  $\chi^2(1) = 2.98$ ,  $p = 0.08$ ; average escape speed,  $\chi^2(1) =$   
415  $1.18$ ,  $p = 0.28$ ; maximum escape speed,  $\chi^2(1) = 0.01$ ,  $p = 0.91$ ; and distance travelled  $\chi^2(1) =$   
416  $1.36$ ,  $p = 0.24$ , and did not change the outcomes of any model. Therefore, distance to  
417 stimulus was not included in the final models.

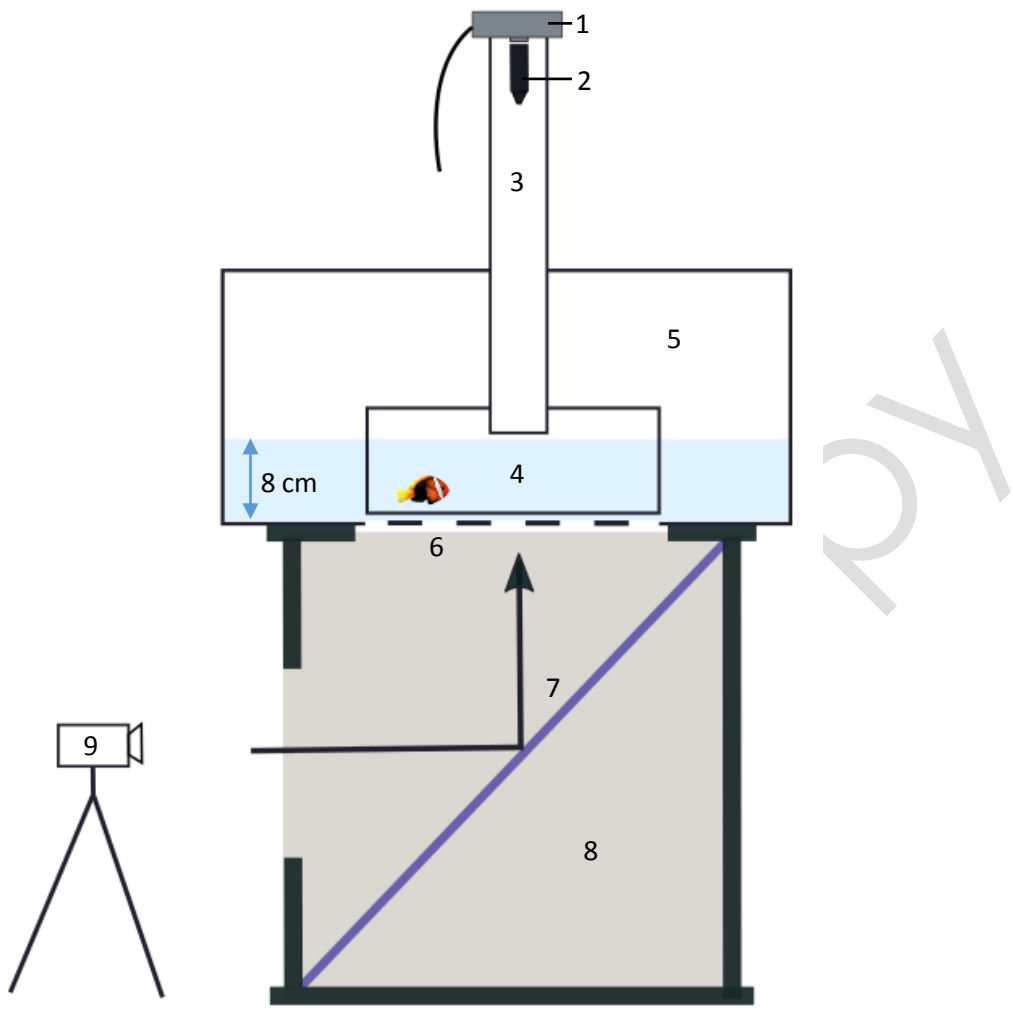
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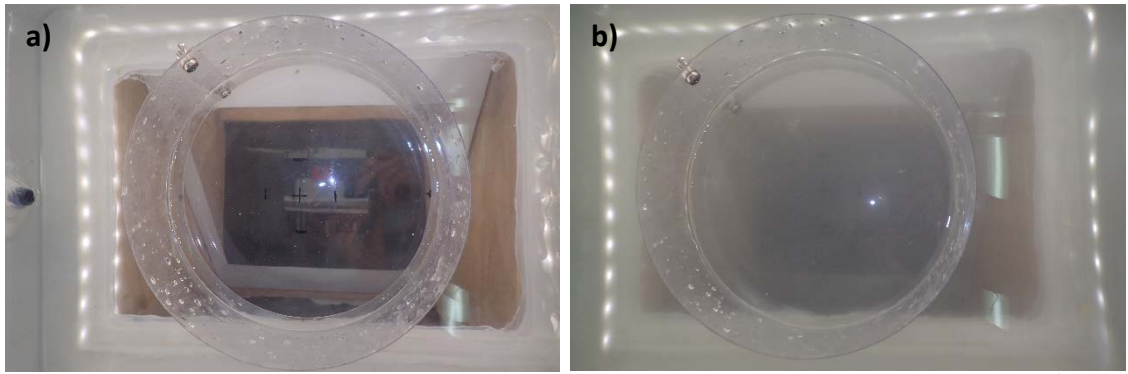
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**Fig. S1.** Experimental set up. 1) Electromagnet, accessible via a remote switch; 2) black weight with tapered end used as a startling stimulus; 3) the stimulus fell through a tube ending 5mm above the water surface to prevent fish from detecting the stimulus before entering the water surface. The stimulus was released once the juveniles swam at least two body lengths away from the wall and one body length away from the tube to avoid edge effects; 4) test arena (210 mm diameter) sitting in 5) an aquarium with opaque walls and top, illuminated by external LED lights (not shown), and filled to 8 cm with water to minimize vertical displacement; 6) the aquarium had a transparent bottom (indicated by the broken line), so the fish could be observed via a 7) mirror, sitting at an angle of 45° inside a 8) box; 9) high speed camera pointed at the mirror.

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**Fig. S2.** Photograph of the experimental arena filled with clear water from the control a) and water from the suspended sediment treatment b). The walls of the aquarium were opaque, while the bottom was transparent.

## 2. Supplementary results

Juvenile *A. melanopus* exposed to suspended sediments for 7 days did not show any changes in maximum acceleration ( $\chi^2(1) = 0.26, p = 0.60$ ) or maximum escape speeds ( $\chi^2(1) = 0.93, p = 0.33$ ) compared to control fish. Acute exposure (i.e. suspended sediments present in the experimental arena) influenced maximum acceleration but not any other fast start variable, i.e. response latency ( $n = 65, \chi^2(1) = 2.57, p = 0.11$ ), turning rate ( $\chi^2(1) = 2.19, p = 0.13$ ), average escape speed ( $\chi^2(1) = 0.15, p = 0.70$ ), maximum escape speed ( $\chi^2(1) = 0.60, p = 0.44$ ), and distance travelled within the first 24 ms ( $\chi^2(1) = 0.22, p = 0.64$ ). There were no significant interactions between 7-day exposure and acute exposure, i.e. response latency ( $\chi^2(1) = 0.09, p = 0.75$ ), turning rate ( $\chi^2(1) = 0.31, p = 0.57$ ), maximum acceleration ( $\chi^2(1) = 1.70, p = 0.19$ ), average escape speed ( $\chi^2(1) = 0.18, p = 0.67$ ), maximum escape speed ( $\chi^2(1) = 0.15, p = 0.69$ ), and distance travelled ( $\chi^2(1) = 0.12, p = 0.72$ ).

Activity and thigmotaxis were influenced by suspended sediment concentrations in the test arena, but not by 7-day exposure to suspended sediments, i.e. activity ( $n = 78, \chi^2(1) = 1.88, p = 0.17$ ) and thigmotaxis ( $\chi^2(1) = 0.64, p = 0.42$ ). There were also no significant interactions between 7-day exposure and acute exposure, i.e. activity ( $\chi^2(1) = 0.00, p = 0.94$ ), and thigmotaxis ( $\chi^2(1) = 2.11, p = 0.14$ ).