Supplementary Table 1. Results of papers investigating effects of pollutants on sociability and group cohesion. Reduced/increased sociability/group cohesion indicates reduction/increase in all measured metrics of group cohesion under at least one treatment. “Results” shows the reported results from each study per stressor and metric tested. “Results summary” shows the overall result from each study based on effect size calculated as part of metanalysis, as shown in Figure 4. Where effect size could not be calculated for a study, the reported result is given, indicated by “reported”. – indicates a negative effect on social behaviour, + indicates a positive effect, and 0 indicates no significant effect. \* after study citation indicates some or all data required for calculating treatment effect sizes could not be obtained for this study.

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| Pollutant type | Metric | Paper | Species | Substance | Treatments | Results | Results summary |
| OrganicOrganicOrganicOrganicOrganicOrganic | Sociability + cohesion | Al Marshoudi et al. 2023  | *Danio rerio* | Aged microplastics, virgin microplastics  | 0, 1000 ppm | No effect on group cohesion. Reduced sociability with aged but not virgin microplastics | – |
| Hong et al. 2021  | *Danio rerio* | Fluoxetine hydrochloride, citalopram hydrobromide,venlafaxine hydrochloride, amitriptyline hydrochloride,sertraline hydrochloride, vortioxetine,paroxetine hydrochloride, fluvoxamine maleateAcetylsalicylic acid,ibuprofen, naproxen,bezafibrite, clofibrate,gemfibrozil | 0, 0.1, 1, 10, 100, 1000 μg l⁻¹ | Reduced sociability and increased cohesion following exposure to most antidepressants, no effect of paroxetine hydrochloride on sociability, reduced cohesion with amitriptyline and sertraline.No effect of most medicines on TCS, increased TCS with acetylsalicylic acid. Increased IID with acetylsalicylic acid and naproxen, reduced with others. No effect of ibuprofen  | + |
| Khursigara et al. 2021  | *Sciaenops ocellatus* | Oil | 200 ppm | No effect on maximum group size, TCS, or DtCS | + |
| Lei et al. 2022  | *Danio rerio* | Deltamethrin | 0, 0.03, 0.1, 0.333 μg l⁻¹ | Increased TCS, increased NND and IID at 0.03 μg l⁻¹, reduced NND and IID at 0.01 μg l⁻¹, increased NND at 0.333 μg l⁻¹ | 0 |
| Lin et al. 2022  | *Danio rerio* | Ammonia | 0, 90000, 180000 μg l⁻¹ | Increased IID, no effect on TCS or time in far zone | – |
| Salahinejad et al. 2022a  | *Danio rerio* | Bisphenol-SEthinylestradiol (EE₂) | 0, 1, 10, 30 μg l⁻¹1μg l⁻¹ | Increased IID and DCS, no effect on number of excursions from group. Increased IID and DCS, no effect on number of excursions from group. | – |
| Salahinejad et al. 2022b | *Danio rerio* | Bisphenol-SEE₂ | Maternal exposure (0, 1, 10, 30 μg l⁻¹)Maternal exposure (1μg l⁻¹) | Reduced IID (10 μg l⁻¹) and TCS (1 μg l⁻¹), increased number of excursions (30 μg l⁻¹), no effect on ACS. Increased number of excursions from shoal | – |
| Sarasamma et al. 2020  | *Danio rerio* | Polystyrene | 0, 0.5, 1.5 ppm | No effect on TCS, ACS, longest duration in social zone, or shoal area. Reduced IID, NND, and furthest neighbour distance | + |
| SociabilitySociabilitySociabilitySociability | Abreu et al. 2016  | *Rhamdia quelen* | Fluoxetine hydrochloride  | 0, 50 μg l⁻¹ | No effect on sociability | + |
| Adedara et al. 2022 | *Danio rerio* | Perfluorooctanoic acid  | 0, 250, 500, 1000 μg l⁻¹ | No effect on sociability | + |
| Altenhofen et al. 2019  | *Danio rerio* | 2,2-dichlorovinyl-dimethylphosphate  | 0, 1000, 5000, 10000 μg l⁻¹ | No effect on sociability | – |
| Ansai et al. 2016  | *Oryzias latipes* | Fluoxetine hydrochloride  | 0, 100 μg l⁻¹ | Increased latency to first contact, reduced number of contacts. No effect on time in contact or distance to conspecifics | – |
| Barcellos et al. 2020  | *Danio rerio* | Aripiprazole | 0, 0.000556, 0.00556, 0.556 μg l⁻¹ | Fewer approaches to shoal at 0.556 μg l⁻¹; no effect on time spent or distance travelled near shoal | 0 |
| Bertram et al. 2018  | *Gambusia holbrooki* | 17b-trenbolone | 0, 0.016 μg l⁻¹ | Reduced TCS and sociability score, increased approaches to shoal, no effect on latency to approach shoal | 0 |
| Brodin et al. 2013  | *Perca fluviatilis* | Oxazepam | 0, 1, 1000 μg l⁻¹ | Reduced sociability | – |
| Brodin et al. 2017  | *Rutilus rutilus* | Oxazepam | 0, 0.84, 200 μg l⁻¹ | No effect on sociability | 0 |
| Burman 2019 (thesis) | *Gasterosteus aculeatus* | Oxazepam | 0, 40 μg l⁻¹ | No effect on sociability | – |
| Calcagno et al. 2016  | *Jenynsia multidentata* | Carbamazepine | 0, 10, 50, 200 μg l⁻¹ | No effect on sociability | – |
| Calvo 2016 (Thesis)  | *Poecilia reticulata* | Oxazepam | 0, 100 μg l⁻¹ | No effect on sociability | – |
| Cerveny et al. 2020  | *Perca fluviatilis* | Oxazepam, bromazepam, temazepam, clobazam, combination | 0, 0.5, 8 μg l⁻¹ | No effect on sociability | – |
| Chen et al. 2023  | *Danio rerio* | PenicillinPolystyrene, UV-treated polystyrene, O₃-treated polystyrene  | 0, 10 μg l⁻¹0, 5 ppm | Fewer approaches to shoal More approaches to shoal with O₃-polystyrene | 0 |
| Correia et al. 2019  | *Danio rerio* | Carbaryl | 0, 10, 100, 1000 μg l⁻¹ | No effect on sociability | + |
| Correia et al. 2022  | *Danio rerio* | Fluoxetine hydrochloride | 0, 0.1, 1, 10 μg l⁻¹ | No effect on sociability | + |
| Dong et al. 2018  | *Carassius auratus* | Hexabromo-cyclododecane | 0, 2, 20, 200 μg l⁻¹ | Less time away from shoal at 200 μg l⁻¹, no effect on times leaving shoal | + |
| Fenske et al. 2020  | *Danio rerio* | 17α-ethinylestradiol | 0, 0.0005 0.0015, 0.0050.05, 0.075 μg l⁻¹ | Reduced TCS and ACS after chronic (15d) exposure, no effect of acute (1h) exposure or on time in far zone | – |
| Giacomini et al. 2016  | *Danio rerio* | Fluoxetine hydrochloride | 0, 16, 50 μg l⁻¹ | Reduced TCS, no effect on ACS, time in far zone, or number of entries to far zone | – |
| Jacquin et al. 2017 | *Poecilia reticulata* | Oil | 0, 500000 ppm, wild exposure clean/polluted | No effect on TCS | 0 |
| Kaplan et al. 2013\* | *Fundulus heteroclitus* | BBP | 0, 100 μg l⁻¹ | Less time with large shoal, more time with small shoal and away from both shoals | – reported |
| Kellner et al. 2016  | *Gasterosteus aculeatus* | Citalopram | 0, 0.09, 1.5 μg l⁻¹ | No effect on latency to leave, times leaving, or time away from shoal | 0 |
| Ligocki et al. 2019  | *Gambusia affinis* | Bifenthrin | 0, 0.001, 0.003, 0.006, 0.012, 0.025 μg l⁻¹ | No effect on ACS or TCS | + |
| Liu et al. 2018  | *Danio rerio* | Triclosan, 2,4,6-trichlorophenol (2,4,6-TCP), 2,4-dichlorophenol (2,4-DCP); mixture ratio 1:2:4 | 0, 140, 280, 560 μg l⁻¹ | Reduced ACS, TCS and DCS | – |
| Liu et al., 2017  | *Carassius carassius* | Erythromycin, Ketoconazole | 0, 2 μg l⁻¹0, 0.2, 2, 20 μg l⁻¹All combinations | Less time away from shoal and less transitions away from shoal with ketoconazole alone, no effect of erythromycin or combination | + |
| Lucon-Xiccato et al. 2023  | *Danio rerio* | Triclocarban | 0, 5, 50 μg l⁻¹ | No effect on sociability score at 5 μg l⁻¹, increased sociability score at 50 μg l⁻¹ | + |
| Mancia et al. 2023 | *Danio rerio* | Virgin microplastics, environmentally contaminated microplastics | 0, 400 μg l⁻¹ | No effect on social preference | 0 |
| Martin et al. 2019  | *Gambusia holbrooki* | Fluoxetine hydrochloride | 0, 0.06, 0.35 μg l⁻¹ | No effect on sociability score or TCS | + |
| Mason et al. 2021  | *Poecilia reticulata* | Fluoxetine hydrochloride | 0, 0.04, 0.36 μg l⁻¹ (maternal exposure) | Increased TCS in paired trials at 0.36 μg l⁻¹, no effect on time with large shoal | 0 |
| Maulvault et al. 2018 | *Argyrosomus regius* | Venlafaxine hydrochloride | 0, 160 μg l⁻¹ (fed), 20 μg l⁻¹ (solution) | Reduced TCS. Reduced LCS (fed). No effect on ACS.  | – |
| McCallum et al. 2017\* | *Neogobius melanostomus* | Fluoxetine hydrochloride | 0, 1, 40 μg l⁻¹ | No effect on TCS | No effect reported |
| Meijide et al. 2018 | *Gambusia holbrooki* | Fluoxetine hydrochloride | 0, 1, 5, 25, 50 μg l⁻¹ | No effect on TCS | + |
| Moriera & Luchiari 2022  | *Danio rerio* | Oxybenzone | 0, 10, 100, 1000 μg l⁻¹ | Lower TCS at 10 μg l⁻¹. No effect on LCS | – |
| Orjes et al. 2015 (thesis) | *Carassius carassius* | Fluoxetine hydrochloride | 0.1, 1, 100 μg l⁻¹ | No effect on TCS | + |
| Petersen et al., 2021  | *Danio rerio* | Ciprofloxacin, ceftazidime, chlortetracycline | 0, 6250 μg l⁻¹ | No effect on time near shoal, time away from shoal, or mean distance from shoal | 0 |
| Porseryd et al. 2017a  | *Danio rerio* | Citalopram17α-ethinylestradiol | 0, 0.0001 μg l⁻¹0, 0.002, 0.007 μg l⁻¹ | Fewer times leaving shoal, no effect on latency to leave or time awayFewer times leaving shoal, no effect on latency to leave or time away | + |
| Porseryd et al. 2017b | *Danio rerio* | EE₂ | 0.4, 0.0009 μg l⁻¹ | No effect on sociability | + |
| Porseryd et al. 2019  | *Gasterosteus aculeatus* | EE₂ | 0.004, 0.03 μg l⁻¹ | Increased latency to leave shoal, fewer times leaving shoal | + |
| Qiu et al. 2020  | *Gobiocypris rarus* | P-chloroaniline3‐aminobenzoic acid ethyl estermethanesulfonate (MS222)Cadmium | 0, 10, 19, 29, 38 mg l⁻¹0, 11, 23, 34, 45 mg l⁻¹0, 3, 7, 10, 13 mg l⁻¹ | Reduced TCS Reduced TCSReduced TCS | – |
| Renick 2014\* | *Fundulus heteroclitus* | Chlorpyrifos | 0, 1, 5 μg l⁻¹ | Increased DCS | – reported |
| Reyhanian et al. 2011 | *Danio rerio* | EE2 | 0, 0.005, 0.025 μg l⁻¹ | Increased latency to leave a shoal, fewer times leaving shoal, less time away from shoal | 0 |
| Sancho Santos et al. 2021  | *Squalius cephalus* | Tramadol hydrochloride | 0, 1 μg l⁻¹ | Increased distance to conspecific | – |
| Santos et al. 2023  | *Danio rerio* | Caffeine | 0, 0.5, 1.5, 300 μg l⁻¹ | Reduced time swimming near conspecific shoal, increased approaches to conspecific shoal. No effect on time spent with or away from shoal, or number of entries to far zone | – |
| Sun et al. 2020  | *Danio rerio* | DiclofenacAquatic colloids | 0, 1.09, 104 μg l⁻¹30 mg l⁻¹ | Increased TCS Increased TCS | + |
| Sunedin 2015 (Thesis) | *Gasterosteus aculeatus* | Oxazepam, fexofenadine, mixture | 0, 2μg l⁻¹ | No effect on sociability score | 0 |
| Takai et al. 2022  | *Oryzias latipes* | DiazepamMicroplastics  | 0, 26, 255 μg l⁻¹9900000 ppm | Increased number of times leaving shoal with both | – |
| Tamagno et al. 2022  | *Danio rerio* | EE2 | 0, 0.00005, 0.0005, 0.005, 0.05, 0.075 μg l⁻¹ | Increased time near shoal and reduced time away from shoal with acclimated (15d) exposure, increased time near shoal but no effect on time away from shoal with acute (1h) exposure | + |
| Volkova et al. 2015  | *Danio rerio* | EE₂ | 0, 0.0012, 0.0016 μg l⁻¹0, 0.0012 μg l⁻¹ (parental exposure) | Increased latency to leave social zone, fewer entries and less time in far zone (direct exposure). No effect of parental exposure | 0 |
| Xia et al. 2010  | *Danio rerio* | Nonylphenol | 0, 0.1, 1, 10, 50, 100 μg l⁻¹ | No effect on times leaving shoal, reduced TCS at 100 μg l⁻¹ | – |
| Zang et al. 2019  | *Danio rerio* | Triclosan | 0, 20000 μg l⁻¹ | No effect on distance travelled near a conspecific shoal | + |
| Zhang et al. 2017  | *Danio rerio* | 2,2′,4,4′-tetrabromodiphenyl ether (BDE-47) | 0, 1.63, 241 μg l⁻¹ | Increased number of contacts and contact time with no recovery time. No effect on number of contacts, reduced average contact time in one trial (4d) with 2-6d recovery | + |
| Group cohesionGroup cohesionGroup cohesion | Aimon et al. 2022  | *Dicentrarchus labrax* | Oil | 0, 400ppm | No effect on group cohesion | + |
| Alfonso et al. 2020  | *Dicentrarchus labrax* | Ammonia | 0, 3, 7, 11, 15 μg l⁻¹ | Reduced group cohesion at ≥ 11 μg l⁻¹ | 0 |
| Armstrong et al. 2019  | *Micropogonias undulatus* | Oil | 0, 0.006, 0.032 ppm | Reduced group cohesion at 0.032 ppm | – |
| Barry 2012  | *Aphanius dispar* | Fluoxetine hydrochloride | 0, 0.03, 0.3, 3 μg l⁻¹ | Increased swimming speed relative to nearest neighbour at 0.03 μg l⁻¹, no effect on NND | 0 |
| Chen et al. 2021a  | *Danio rerio* | Tetrabromobisphenol A (TBBPA) | 0, 1.09 μg l⁻¹ | Reduced cohesion, no effect on sociability | – |
| Chen et al. 2022  | *Cyprinus carpio* | GlyphosatePolyethylene microplastics | 0, 5000, 15000 μg l⁻¹ glyphosate, 0, 1500, 4500 μg l⁻¹ microplastics,  | No effect on number of interactions between fish | 0 |
| Eslava-Mocha et al. 2019\* | *Piaractus brachypomus* | Polyethyloxylated tallow amine POEA-TA15 | 0, 200, 500, 1000, 2000,4000, 8000,16000, 32000,70000,140000 μg l⁻¹ | Less cohesive schooling pattern | – reported |
| Fahlman et al. 2021  | *Perca fluviatilis* | Oxazepam | 0, 14.9 μg l⁻¹ | Reduced NND  | + |
| Faria et al. 2021  | *Danio rerio* | Glyphosate (N-phosphonomethyl-glycine) | 0, 0.27, 3.38 μg l⁻¹ | Reduced IID and maximum interfish distance | + |
| Hamilton et al. 2018  | *Anchoa lamprotaenia, A. lyolepis* | SKF 38393 hydrochloride, SCH 23390 hydrochloride | 0, 1000, 10000 μg l⁻¹ | No effect on NND or IID | + |
| Hamilton et al. 2022  | *Danio rerio* | Benzo[a]pyrene | 0, 252.3, 2523, 25230 μg l⁻¹ | Increased IID at 25230 μg l⁻¹ | 0 |
| Holcombe et al. 1980\* | *Pimephales promelas* | 2,4-dichlorophenol, 2,4-dichlorophenol + NaOH | 8230, 8450, 7430 + NaOH,12330 + NaOH μg l⁻¹ | No effect on schooling pattern | No effect reported |
| Huang et al. 2021  | *Danio rerio* | Deltamethrin | 0, 15 μg l⁻¹ | Increased IID after 2h exposure | + |
| Johansen et al., 2017  | *Pomacentrus amboinensis, Pomacentrus moluccensis* | Oil | 0, 0.0025, 0.0057 ppm | Reduced shoal size in both species at 0.0057 ppm | – |
| Khalil et al. 2013  | *Oryzias latipes* | Chlorpyrifos | 0, 12 μg l⁻¹ | Reduced solitary duration at 8d exposure. No effect at 4d exposure. No effect on solitary frequency, shoaling or schooling frequency or duration | + |
| Khalil et al. 2017  | *Oryzias latipes* | Chlorpyrifos | 0, 12, 120 μg l⁻¹ | Reduced shoaling & schooling frequency & duration, increased solitary duration. No effect on solitary frequency | – |
| Lal et al. 1984\*  | *Cirrhinus mrigala* | Alkyl benzene sulphonate | 0, 0.015 μg l⁻¹ | No effect on schooling pattern | No effect reported |
| Lanzarin et al. 2020  | *Danio rerio* | Glyphosate (N-phosphonomethyl-glycine) | 0, 1320, 1940, 5030 μg l⁻¹  | No effect on NND or IID | – |
| Leite et al. 2023  | *Luciobarbus bocagei**Alburnus alburnus* | Esfenvalerate | 0, 1.2, 2 μg l⁻¹ | Reduced cohesion index in *L. bocagei*, no effect on *A. alburnus* | – |
| Mattson et al. 2018  | *Carassius carassius* | Polystyrene | Food chain exposure | Reduced IID | + |
| Nakayama et al. 2005 | *Oryzias latipes* | Polychlorinated biphenols (PCBs) | 0, 1, 5, 25, 125 μg l⁻¹ | Increased NND at 25 μg l⁻¹. No effect on MDCS, time in shoal, or polarity | – |
| Qiu et al. 2022  | *Danio rerio* | Amitriptyline | 0, 2.5, 40 μg l⁻¹ | Reduced frequency and duration of schooling following 21d recovery, increased duration of schooling with no recovery.  | 0 |
| Saglio & Trijasse 1998  | *Carassius auratus* | Atrazine, diuron | 0, 0.5, 5, 50 μg l⁻¹ (static water)0, 0.1, 1, 10 μg l⁻¹ (flowing water) | Fewer fish shoaling in static treatments. No effect on flow treatments | – |
| Saglio et al. 2001  | *Carassius auratus* | Prochloraz, bentazone, nicosulfuron | 0, 10, 100, 1000, 10000 μg l⁻¹ | No effect on grouping behaviour | 0 |
| Saglio et al. 2003  | *Carassius auratus* | Prochloraz | 0, 25, 50, 100 μg l⁻¹ | Increased grouping behaviour at 4-6d exposure; no effect at 2 and 8d | + |
| Santos et al. 2020  | *Danio rerio* | Microplastics  | 2 ppm | No effect on IID or NND | + |
| Santos et al. 2021  | *Danio rerio* | Microplastics  | 2 ppm | No effect on IID or NND | + |
| Schmidel et al. 2014  | *Danio rerio* | Atrazine | 0, 10, 1000 μg l⁻¹ | No effect of 10 μg l⁻¹, increased IID, NND, furthest neighbour distance, and shoal area, and reduced contacts and cohesion index at 1000 μg l⁻¹ | – |
| Ward et al. 2008\*  | *Fundulus diaphanus* | 4-nonylphenol | 0, 1 μg l⁻¹ | Increased NND | – |
| Weis & Weis 1974a  | *Menidia menidia* | Sevin | 0, 0.1 μg l⁻¹ | Increased school area, no effect on polarity | – |
| Weis & Weis 1974b\* | *Carassius auratus* | Dichloro-diphenyl-trichloroethane (DDT) | 0, 1 μg l⁻¹ | Increase school area at 3d exposure, reduced polarity and 3-7d exposure. No effect at 1 and 14d | – reported |
| Williams 1989\* | *Dicentrarchus labrax* | Methyl parathion | 0, 2500, 5000, 10000 μg l⁻¹ | Increased duration of approach-orientation at 5000 μg l⁻¹ 24h exposure; reduced duration of parallel orientation, reduced frequency of realignment | – reported |
| Yofukuji et al. 2021  | *Moenkhausia forestii* | Sugarcane ash | 0, 800 mg l⁻¹ | No effect on number of isolated individuals | – |
| Zhang et al. 2018  | *Danio rerio* | 6-OH-BDE-476-MeO-BDE-47 | 0, 1.31, 7.03 μg l⁻¹0, 1.64, 12.6 μg l⁻¹ | No effect on time per contactReduced time per contact at 6d exposure (no effect at 5d) | – |
| Inorganic | Sociability + cohesion | Al Marshoudi et al. 2023 | *Danio rerio* | Cadmium | 0, 50 μg l⁻¹ | No effect on sociability or group cohesion | – |
| Zhang et al. 2016  | *Gobiocypris rarus* | Tributyltin | 0, 0.88, 9.2, 93 ng l⁻¹ | Reduced cluster score, latency to leave shoal, and movements away from shoal. Increased time away from shoal | – |
| Sociability | Attaran et al. 2019  | *Danio rerio* | Selenomethionine | 0, 2.1, 11.6, 31.5 μg l⁻¹ | Reduced sociability at ≥11.6 μg l⁻¹, no effect on group cohesion | 0 |
| Attaran et al. 2021  | *Danio rerio* | Selenomethionine | 3.6, 12.8, 34.1 μg l⁻¹ | Reduced sociability at 34.1 μg l⁻¹ | – |
| Bowser 2021 (Thesis)  | *Fundulus heteroclitus* | Arsenic | 0, 10, 500 ppb | No effect on sociability | – |
| Capriello et al. 2021  | *Danio rerio* | Aluminium | 0, 11000 μg l⁻¹ | Reduced sociability at 15d exposure, no effect at 10d and 20d | – |
| Chen et al. 2021b  | *Danio rerio* | Titanium dioxide (TiO₂) nanoparticles | 0, 100, 1000 μg l⁻¹ | Increased time in social (mirror) zone | 0 |
| da Silva Acosta et al. 2016  | *Danio rerio* | Copper | 0, 5, 9, 20, 60 μg l⁻¹ | No effect on time spent near conspecific shoal | + |
| Qiu et al. 2020 | *Gobiocypris rarus*  | Cadmium | 0, 3000, 7000, 10000, 13000 μg l⁻¹ | Reduced TCS | – |
| Vogt et al. 2013  | *Heterandria formosa* | Copper | 1, 25, 50, 100 μg l⁻¹ (2h or 7d exposure) | Reduced TCS and increased time to first shoaling in acute exposure (2h), no effect in chronic exposure (7d) | – |
| Ward et al. 2013  | *Morone americana* | Copper | 0, 5 μg l⁻¹ | No effect on sociability | – |
| Group cohesion | Chen et al. 2021a  | *Danio rerio* | Titanium dioxide (TiO₂) | 0, 100 μg l⁻¹ | Reduced time in contact but no effect on rate of contacts  | – |
| David et al. 2015\* | *Labeo rohita* | Sodium cyanide | 0, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330 μg l⁻¹ | Less cohesive schooling pattern | – reported |
| Huang et al. 2021  | *Danio rerio* | Cadmium | 0, 3500 μg l⁻¹ | Reduced IID at 1-2h exposure | 0 |
| Iwama et al. 1986\*  | *Danio rerio* | Sodium pentachlorophenate | 0, 3.9, 39 μg l⁻¹ | Less cohesive schooling at 39 μg l⁻¹ | – reported |
| Koltes, 1985 | *Menidia menidia* | Copper | 0, 100 μg l⁻¹ | Reduced NND, no effect on polarity | + |
| Lu et al. 2017 | *Danio rerio* | ZincChromium | 0, 10000, 20000, 30000 μg l⁻¹12500, 25000, 40000 μg l⁻¹ | Reduced IID, no effect on shoal area with zinc. No effect of chromium | + |
| Ososkov & Weis 1996 | *Fundulus heteroclitus* | Methylmercury | 0, 5, 10 μg l⁻¹Clean & polluted origin fish (0, 11.2 μg l⁻¹ wild exposure) | Reduced IID and increased polarity (polluted origin); increased polarity (clean origin). Increased IID & polarity in polluted vs. clean origin fish | + |
| Petitjean et al. 2021\* | *Gobio occitaniae* | Cadmium + copper + zinc | 0.007/0.62/4.06, 13.5/9.96/551 μg l⁻¹ | No effect on NND or number of contacts | No effect reported |
| Santos et al. 2023 | *Danio rerio* | ZincChromium | 0, 10000, 20000, 30000 μg l⁻¹0, 12500, 25000, 40000 μg l⁻¹ | Reduced IID with zinc, no effect of chromium or on shoal area | + reported |
| Santos et al. 2020 | *Danio rerio* | Copper | 2, 17.1, 51.9, 131 μg l⁻¹ | No effect on IID or NND | + |
| Santos et al. 2021 | *Danio rerio* | Copper | 2.42, 52.9, 133 μg l⁻¹ | No effect on IID or NND | + |
| Shelton et al., 2023 | *Danio rerio* | Cadmium | Two of six fish exposed to 0, 1 μg l⁻¹ | No effect on NND or shoal size | 0 |
| Zhao et al. 2020 | *Danio rerio* | Lead | 0, 4.5, 9.62, 18.6 μg l⁻¹ | Increased number of contacts at 18.6 μg l⁻¹  | + |
| Mixture | Sociability + cohesion | Al Marshoudi et al. 2023 | *Danio rerio* | Cadmium + microplastics | 0, 50 μg l⁻¹ + 1000 ppm | No effect on sociability or group cohesion | – |
| Sociability | Alfonso et al. 2022 | *Danio rerio* | PCBs & PBDEs  | 0, 1.93 μg l⁻¹ | No effect on sociability | – |
| Bailey & Levin 2015  | *Danio rerio* | Firemaster 550 | 10, 100, 1000, 3000 μg l⁻¹ | Reduced sociability following 5d exposure with 40d recovery and 1d exposure with no recovery. No effect of 1d exposure with 7d recovery | – |
| Cerveny et al. 2020  | *Perca fluviatilis* | Oxazepam + bromazepam + temazepam + clobazam | 0, 0.5 each, 8 each μg l⁻¹ | No effect on sociability | – |
| Chagas et al. 2019 | *Danio rerio* | Tannery effluent | 0, 1000000, 3000000 μg l⁻¹ | Increased ACS, increased TCS at 3000000 μg l⁻¹ | + |
| Chen et al. 2023  | *Danio rerio* | O₃-treated polystyrene + penicillin | 0, 5 ppm + 10 μg l⁻¹ | More approaches to shoal with O₃-polystyrene and O₃-polystyrene with penicillin.  | 0 |
| Mehdi et al. 2022\*  | *Pimephales promelas* | Wastewater  | 250000000, 500000000 μg l⁻¹ | Less time interacting with conspecific at 5e8 μg l⁻¹. No effect on TCS.  | – |
| Porseryd et al. 2017b | *Danio rerio* | EE₂ + citalopram  | 0.0009 + 0.0001 μg l⁻¹ citalopram | No effect on sociability | + |
| Sun et al. 2020  | *Danio rerio* | Diclofenac + aquatic colloids | 0, 0.9, 96.3 μg l⁻¹ + 30 mg l⁻¹ | Increased TCS  | + |
| Takai et al. 2022  | *Oryzias latipes* | Diazepam + microplastics | 0.026 μg l⁻¹ + 9900000 ppm | Increased number of times leaving shoal  | – |
| Toft et al. 2015  | *Gambusia holbrooki* | Paper mill effluent | Wild exposure | Reduced attending and positioning behaviour | – |
| Ward et al. 2013  | *Morone americana* | Copper + 4-nonylphenol | 0, 2 + 5 μg l⁻¹ | No effect on sociability | + |
| Group cohesion | Chen et al. 2021a  | *Danio rerio* | Tetrabromobisphenol A (TBBPA) + Titanium dioxide (TiO₂),  | 0, 1.09 μg l⁻¹ + 100 μg l⁻¹ | Reduced time in contact but no effect on rate of contacts  | – |
| Chen et al. 2022  | *Cyprinus carpio* | Glyphosate + microplastics | 0, 5000, 15000 μg l⁻¹ glyphosate + 0, 1500, 4500 μg l⁻¹ microplastics,  | No effect on number of interactions between fish | 0 |
| Santos et al. 2020  | *Danio rerio* | Copper + microplastics | 15, 60, 125 μg l⁻¹ + 2ppm | Reduced NND and IID at 125 μg l⁻¹ | + |
| Santos et al. 2021 | *Danio rerio* | Copper + microplastics | 2.42, 52.9, 133 μg l⁻¹ + 2ppm | No effect on IID or NND | + |
| Light | Sociability | Kurvers et al. 2018  | *Poecilia reticulata* |  | 24h 5000 lx, 12h 5000 lx 12h 0.5 lx, 12h 5000 lx, 12h 0 lx | No effect on TCS | 0 |
| Lucon-Xiccato et al. 2022  | *Oryzias latipes* | 8h:16h light/dark; 16h:8h light/dark | 0, 900 lx | Reduced TCS in second half of trial | 0 |
| Matchette et al. 2021  | *Gasterosteus aculeatus* | Visual noise | Statics, slow, medium, fast  | No effect on larger shoal choice, reduced DCS | + |
| Zhang et al. 2017 | *Danio rerio* | Day/night | 0, 900 lx | No effect on number of contacts or average contact time  | – |
| Group cohesion | Bierbach et al. 2018  | *Poecilia mexicana* |  | 6000 lx | Reduced cohesion with live conspecific, no effect with robot conspecific | + |
| Burbano Lombano et al. 2022  | *Danio rerio* |  | 0, 250 lx | Reduced IID with and without flow, increased polarity with flow | + |
| Butail et al. 2015  | *Devario aequipinnatus* | Bright-to-dark, dark-to-bright | 1, 250 lx | Increased group cohesion | + |
| Chaput et al. 2022  | *Danio rerio* | Day/night | 0, 900 lx | Increased cohesion | + |
| Clark 2022 (thesis)  | *Gasterosteus aculeatus* | White noise | 2057.5, 5132.6, 6797.3, 8512.4 lx | Reduced cohesion | – |
| Fahlman et al. 2021  | *Perca fluviatilis* | Day/night | 0, 900 lx | No effect on group cohesion | – |
| Kelley et al. 2012  | *Melanotaenia australis* | Neutral filter, yellow filter  | 0.616, 0.449lx | Higher IID with yellow filter, no effect of neutral filter | – |
| Khait et al. 2009  | *Mormyrus proboscirostris* |  | 0.18, 237 lx | Increased NND in light at 49 and 65d exposure, reduced NND at 245d  | 0 |
| Lafoux et al. 2023\* | *Hemigrammus rhodostomus* | Day/night | 0, 900 lx | Increased IID and NND, reduced polarity | – reported |
| Marchesan et al. 2005 | *Dicentrarchus labrax, Mugil cephalus, Lithognathus mormyrus, Sparus aurata* | Increasing or decreasing light level; increasing or decreasing wavelength | 0.2-680 lx410-650 nm | Increased cohesion in light in *L. mormyrus* and *S. aurata*. Increased cohesion at higher wavelengths in *M. cephalus*. Reduced cohesion in light and under increasing wavelength in *Di. labrax*; increasing cohesion under reducing wavelength | 0 |
| Neo et al. 2018\*  | *Dicentrarchus labrax* | Day/night | 0, 900 lx | Reduced IID in light | + reported |
| Olla & Studholme 1971  | *Pomatomus saltatrix* | Day/night | 0, 900 lx | Increased sociability index  | + |
| Patch et al. 2022\*  | *Astyanax mexicanus* |  | 0, 32 lx | Increased polarity | + reported |
| Ryer & Olla 1998  | *Gadus chalcogrammus* | 12h light 12h darkGradual light reduction | 0, 21 lx0-39 lx | Reduced NND in both treatments | + |
| Sogard & Olla 1996  | *Gadus chalcogrammus* |  | 0.3, 40 lx | Reduced NND and cohesion index | + |
| Zhang et al. 2018 | *Danio rerio* | Day/night | 0, 900 lx | No effect on cohesion | 0 |
| Zhao et al. 2020 | *Danio rerio* | Day/night | 0, 900 lx | Fewer but longer contacts in light vs. dark (0 μg l⁻¹) | 0 |
| NoiseNoise | Sociability | Hanache et al. 2018  | *Phoxinus phoxinus* | Boat noise | 25, 35 dB | No effect on distance to conspecific | + |
| Group cohesionGroup cohesion | Clark 2022 (thesis)  | *Gasterosteus aculeatus* | White noise | 108.5, 135 dB | No effect on cohesion | + |
| Currie 2021 (thesis)\*  | *Rutilus rutilus**Cyprinus carpio* | Simulated background noise, pulse toneArtificial ambient sound, white noise | 110, 145 dB110, 121, 130 dB | No effect on cohesionIncreased cohesion | + |
| Currie et al. 2020  | *Phoxinus phoxinus* | Sinewave 150Hz | 72, 155 dB continuous, slow, intermediate, fast pulses | No effect on cohesion | + |
| Currie et al. 2021  | *Phoxinus phoxinus* | Sinewave tones, octave band noise,  | 80, 150 dB150, 2200 Hz | No effect on MDCS. Reduced orientation angle (increased cohesion) at 2200Hz sinewave tone noise | + |
| Duarte et al. 2019  | *Leporinus taeniatus* | Hydroelectric turbine noise | Ambient, 100dB | More unpolarized fish, no effect on polarized fish | 0 |
| Fewtrell and McCauley 2012\* | *Pagrus auratus* | Air gun | 100, 185 dB | No effect on schooling pattern | No effect reported |
| Ginnaw et al. 2020  | *Gasterosteus aculeatus* | Acoustic playback | 108, 123 dB | No effect on NND, polarity or heading (inverse polarity) | + |
| Herbert-Read et al. 2017  | *Dicentrarchus labrax* | Pile-driving sound | 116, 129 dB | Reduced polarity (heading), no effect on NND or MDCS | + |
| Hubert et al. 2020  | *Dicentrarchus labrax* | Brown noise | 123, 163 dB | No effect on IID | – |
| Kastelein et al. 2017\* | *Dicentrarchus labrax* | Pile-driving sound | 130, 136, 142, 148, 154, 160, 166 dB | Reduced IID at 148 vs. 136 dB  | + reported |
| Kok et al. 2021  | *Gadus morhua* | Seismic survey, pile-driving | 95, 195 dB78, 172 dB | Greater cohesion under both noise treatments | + |
| Mauro et al. 2020  | *Sparus aurata* | White noise | 115, 145 dB63, 125, 500, 1000 Hz | Reduced school area | – |
| Neo et al. 2014\* | *Dicentrarchus labrax* | Brown noise (continuous/intermittent) | 115, 165, 172 dB | No effect on NND | No effect reported |
| Neo et al. 2015a | *Danio rerio* | White noise (continuous, intermittent 1-1, intermittent 1-9, intermittent irregular) | 89, 112 dB | Reduced IID with intermittent 1-1 noise | + |
| Neo et al. 2015b\* | *Dicentrarchus labrax* | Brown noise (0.25, 0.5, 1, 2 pps) | 104, 158 dB | Reduced IID at 1pps | + reported |
| Neo et al. 2016  | *Dicentrarchus labrax* | Brown noise (continuous, impulsive regular, impulsive irregular, impulsive regular with ramp-up) | 108, 167 (continuous), 186 (impulsive) | No effect on IID | + |
| Neo et al. 2018  | *Dicentrarchus labrax* | Brown noise  | 100, 192 dB | No effect on group cohesion | + |
| Rojas et al. 2023\* | *Rutilus rutilus* | Motorboat noise | 92 dB (control), not reported | Increased shoal area | – reported |
| Short et al. 2020  | *Phoxinus phoxinus* | Random noise | Not reported (control), 152 dB | Increased standard deviation of fish location | + |
| van der Knaap et al. 2022\* | *Clupea pallasii,* *Oncorhynchus gorbuscha,* *Oncorhynchus keta* | Motorboat noise | 105, 117, 123, 146 dB | Increased school cohesion in all species  | + reported |
| Voellmy et al. 2014  | *Phoxinus phoxinus* | Cargo ship noise | 70, 115 dB | No effect on number of contacts | + |
|  Turbidity | Sociability | Fischer et al. 2013  | *Gasterosteus aculeatus* | Green algae | 0, 0.016 NTU | No effect on TCS, reduced preference for larger shoal and fewer changes between shoals | – |
| Kimbell & Morrell 2016  | *Pungitius pungitius* | Algae | 0, 12.5 NTU | Less time spent with similarly sized conspecifics, no effect on TCS | 0 |
| Group cohesion | Aspbury et al. 2019  | *Etheostoma fonticola* | Light filters | 0, 40 NTU | Reduced preference for large conspecifics, no effect on time interacting with a conspecific | – |
| Borner 2016 (thesis)  | *Poecilia reticulata* | Clay | 0, 300, 800 NTU | Increased IID but reduced time alone in clear source fish. Reduced IID but fewer initiated associations in turbid fish source fish | – |
| Borner et al. 2015  | *Poecilia reticulata* | Clay | 0, 850 NTU | Reduced group cohesion | – |
| Clark 2022 (thesis)  | *Gasterosteus aculeatus* | White noise | 2.72, 5.25, 13.09, 36.43 NTU | No effect on cohesion | + |
| Ehlman et al. 2019\* | *Gambusia affinis* | Clay | 0, 20, 40 NTU | No effect on IID or number of nearest neighbours | No effect reported |
| Gray et al. 2014  | *Notropis anogenus, N. bifrenatus, N. heterodon, N. heterolepsis, N. volucellus* |  | 0.33, 0.61, 1.53, 1.58, 2.1, 2.45, 2.99, 3.84, 4.65, 5.70, 6.97 NTU | Reduced proportion of fish shoaling in *N anogenus* and *N. bifrenatus*. No effect on other species | – |
| Kimbell & Morrell 2015a  | *Poecilia reticulata* | Clay | 0, 50, 100, 200 NTU | Increased IID at 100 and 200 NTU | – |
| Kimbell & Morrell 2015b  | *Poecilia reticulata* | Algae | 0, 20 NTU | No effect on number of near neighbours | 0 |
| Langenhof et al. 2016 | *Gasterosteus aculeatus* |  | 0.05, 57, 66, 75, 93, 111, 138 NTU | No effect on number of fish within one BL | + |
| Macpherson 1998  | *Diplodus puntazzo, D. sargus, D. vulgaris* |  | 10, 20 NTU | No effect on shoal size | – |
| Michael et al. 2021  | *Cyprinella lutrensis, Notropis stramineus* | Clay | 0, 100, 250 NTU | Increased NND and shoal area | – |
| Ohata et al. 2014  | *Engraulis japonicus, Plecoglossus altivelis, Seriola quinqueradiata* | Kaolin clay | 0, 1.5, 5.8, 14.6, 87.7 NTU | Increased polarity in *E. japonicus* and *P. altivelis*, reduced NND in *P. altivelis* and *S. quinqueradiata* at 5.8-14.6 NTU, increased NND at 87.7 NTU in *S. quinqueradiata* | + |
| Suriyampola et al. 2018  | *Danio rerio* | Clay | 1, 60.1 NTU | No effect on MDCS | + |

TCS = time near conspecific shoal; IID = inter-individual distance; DtCS = distance travelled near a conspecific shoal; NND = nearest neighbour distance; ACS = approaches to a conspecific shoal; DCS = distance to a conspecific shoal; LCS = latency to approach a conspecific shoal; MDCS = mean distance to the centre of the shoal. NTU = nephelometric turbidity units.

Supplementary Table 2. Results of phylogeny-adjusted MCMCglmm on the effects of organic

contaminants on sociability and group cohesion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Posteriormean | Lower 95% CI | Upper 95% CI | Effective sample size | *p* |
| Intercept | -0.374 | -4.849 | 3.696 | 2400 | 0.851 |
| Pollutant concentration (zscore) | -0.029 | -0.155 | 0.090 | 2400 | 0.678 |
| Group size | -0.011 | -0.062 | 0.035 | 2400 | 0.682 |
| Replicates | 0.006 | -0.004 | 0.015 | 2481 | 0.260 |
| Exposure period (days) | -0.001 | -0.003 | 0.001 | 2400 | 0.420 |
| Metric (sociability) | -0.483 | -0.794 | -0.192 | 2400 | <0.001\*\*\* |
| Exposure type (Acute) | -0.012 | -0.238 | 0.213 | 2400 | 0.898 |
| Exposure type (Developmental) | 0.211 | -0.580 | 0.992 | 2079 | 0.593 |
| Exposure type (Parental) | -0.054 | -0.782 | 0.576 | 2400 | 0.879 |
| Zscore\*metric | -0.079 | -0.350 | 0.208 | 2400 | 0.563 |

Supplementary Table 3. Results of phylogeny-adjusted MCMCglmm on the effects of inorganic

contaminants on sociability and group cohesion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Posteriormean | Lower 95% CI | Upper 95% CI | Effective sample size | p |
| Intercept | 0.419 | -2.825 | 4.243 | 2255 | 0.729 |
| Pollutant concentration (zscore) | 0.073 | -0.150 | 0.256 | 2400 | 0.482 |
| Group size | -0.104 | -0.197 | 0.001 | 2454 | <0.05\* |
| Replicates | -0.004 | -0.013 | 0.005 | 2655 | 0.423 |
| Exposure period (days) | -0.004 | -0.033 | 0.028 | 2400 | 0.713 |
| Metric (sociability) | -0.697 | -1.273 | -0.185 | 2175 | <0.05\* |
| Exposure type (Acute) | -0.609 | -1.381 | 0.109 | 2400 | 0.120 |
| Exposure type (Parental) | -0.670 | -3.309 | 1.641 | 2209 | 0.633 |
| Exposure type (Uncontrolled) | 0.147 | -2.789 | 2.806 | 2400 | 0.793 |
| Zscore\*metric | -1.344 | -2.061 | -0.689 | 2400 | <0.001\*\*\* |

Supplementary Table 4. Results of phylogeny-adjusted MCMCglmm on the effects of mixed

contaminants on sociability and group cohesion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Posteriormean | Lower 95% CI | Upper 95% CI | Effective sample size | p |
| Intercept | -45.42 | -74.33 | -15.44 | 396.0 | <0.01\*\* |
| Pollutant concentration (zscore) | -121.7 | -196.5 | -43.80 | 396.0 | <0.01\*\* |
| Group size | -0.200 | -0.355 | -0.058 | 396.0 | <0.01\*\* |
| Replicates | -0.010 | -0.045 | 0.021 | 669.5 | 0.566 |
| Exposure period (days) | 0.001 | -0.005 | 0.007 | 396.0 | 0.788 |
| Metric (sociability) | 46.00 | 19.11 | 77.81 | 396.0 | <0.01\*\* |
| Exposure type (Acute) | -0.693 | -1.184 | -0.095 | 463.9 | <0.05\* |
| Exposure type (Developmental) | 0.319 | -0.504 | 1.174 | 643.5 | 0.485 |
| Exposure type (Parental) | -0.198 | -1.426 | 1.019 | 396.0 | 0.737 |
| Exposure type (Uncontrolled) | -2.697 | -4.107 | -1.462 | 396.0 | <0.05\* |
| Zscore\*metric | 122.7 | 44.82 | 197.5 | 396.0 | <0.01\*\* |

Supplementary Table 5. Results of phylogeny-adjusted MCMCglmm on the effects of noise on

sociability and group cohesion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Posteriormean | Lower 95% CI | Upper 95% CI | Effective sample size | p |
| Intercept | -0.188 | -2.073 | 3.131 | 1867 | 0.683 |
| Noise level (dB) | -0.001 | -0.012 | 0.010 | 1867 | 0.899 |
| Group size | -0.063 | -0.166 | 0.043 | 1437 | 0.242 |
| Replicates | 0.017 | -0.020 | 0.053 | 2302 | 0.354 |
| Exposure period (days) | -4.059 | -7.006 | -1.123 | 1867 | <0.05\* |
| Metric (sociability) | -1.140 | -4.558 | 2.269 | 1867 | 0.512 |
| Exposure type (Uncontrolled) | 407.6 | 114.7 | 701.3 | 1867 | <0.05\* |
| Noise level\*metric | 0.037 | -0.028 | 0.101 | 1530 | 0.251 |

Supplementary Table 6. Results of phylogeny-adjusted MCMCglmm on the effects of light on

sociability and group cohesion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Posteriormean | Lower 95% CI | Upper 95% CI | Effective sample size | p |
| Intercept | 4.251 | -8.008 | 17.18 | 1567 | 0.446 |
| Light level | -0.00001 | -0.001 | 0.001 | 1634 | 0.958 |
| Group size | -0.365 | -0.823 | 0.135 | 138.9 | 0.123 |
| Replicates | -0.198 | -0.397 | 0.018 | 355.6 | 0.063 |
| Exposure period (days) | 0.051 | -0.065 | 0.164 | 1578 | 0.352 |
| Metric (sociability) | -3.176 | -5.226 | -1.154 | 1475 | < 0.01\*\* |
| Exposure type (Acute) | 0.095 | -1.654 | 1.923 | 2092 | 0.919 |
| Exposure type (Repeated) | 0.302 | -1.506 | 2.282 | 1867 | 0.783 |
| Exposure type (Uncontrolled) | -7.258 | -22.10 | 7.890 | 1417 | 0.339 |
| Treatment (lx or nm) | 3.133 | -1.463 | 7.792 | 2071 | 0.207 |
| Light exposure\*metric | 0.00006 | -0.001 | 0.001 | 1787 | 0.906 |
| Light exposure\*treatment | -0.005 | -0.013 | 0.003 | 2072 | 0.217 |

Supplementary Table 7. Results of phylogeny-adjusted MCMCglmm on the effects of turbidity on

sociability and group cohesion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Posteriormean | Lower 95% CI | Upper 95% CI | Effective sample size | p |
| Intercept | 4.023 | -7.826 | 16.92 | 1937 | 0.453 |
| Turbidity (NTU) | 0.00002 | -0.001 | 0.001 | 1416 | 0.973 |
| Group size | -0.291 | -0.754 | 0.177 | 146.5 | 0.205 |
| Replicates | -0.182 | -0.382 | 0.033 | 505.7 | 0.096 |
| Exposure period (days) | 0.050 | -0.058 | 0.155 | 1867 | 0.356 |
| Metric (sociability) | -3.011 | -4.673 | -1.126 | 1261 | < 0.001\*\*\* |
| Exposure type (Acute) | 0.220 | -1.327 | 1.901 | 1867 | 0.782 |
| Exposure type (Parental) | -6.803 | -21.39 | 7.768 | 1058 | 0.363 |
| Exposure type (Uncontrolled) | 3.216 | -1.292 | 7.797 | 1867 | 0.166 |
| Turbidity\*metric | 0.000 | -0.001 | 0.001 | 1413 | 0.966 |