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Bibliography

- Amorim, M.** (2006). Diversity of sound production in fish. In *Communication in fishes Vol 1* (ed. Ladich, F., Collin, S. P., Moller, P. and Kapoor, B. G.), pp. 71–105. Enfield: Science Publishers.
- Anderson, P. A., Berzins, I. K., Fogarty, F., Hamlin, H. J. and Guillette Jr., L. J.** (2011). Sound, stress, and seahorses: The consequences of a noisy environment to animal health. *Aquaculture* **311**, 129–138.
- Bejder, L., Samuels, A., Whitehead, H., Finn, H. and Allen, S.** (2009). Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. *Mar. Ecol. Prog. Ser.* **395**, 177–185.
- Bell, R., Röer, J. P., Dentale, S. and Buchner, A.** (2012). Habituation of the irrelevant sound effect: evidence for an attentional theory of short-term memory disruption. *J. Exp. Psychol. Learn. Mem. Cogn.* **38**, 1542–57.
- Benda-Beckmann, A. M. von, Aarts, G. M., Sertlek, O. S., Lucke, K., Bemmelen, R. van, Wees, R. M. M. van, Verboom, W. C., Kastelein, R. A., Ketten, D. R., Lam, F.-P. A., Kirkwood, R. L., Ainslie, M. A..** (2015). Assessing the impact of underwater clearance of historical explosives on harbour porpoises (*Phocoena phocoena*) in the southern North Sea. *Aquat. Mamm.* **41**, 503–523.
- Benhaïm, D., Péan, S., Lucas, G., Blanc, N., Chatain, B. and Bégout, M.-L.** (2012). Early life behavioural differences in wild caught and domesticated sea bass (*Dicentrarchus labrax*). *Appl. Anim. Behav. Sci.* **141**, 79–90.
- Best, J. D., Berghmans, S., Hunt, J. J. F. G., Clarke, S. C., Fleming, A., Goldsmith, P. and Roach, A. G.** (2008). Non-associative learning in larval zebrafish. *Neuropharmacology* **33**, 1206–15.
- Blaser, R. E., Chadwick, L. and McGinnis, G. C.** (2010). Behavioral measures of anxiety in zebrafish (*Danio rerio*). *Behav. Brain Res.* **208**, 56–62.
- Blaxter, J. H. S., Gray, J. A. B. and Denton, E. J.** (2009). Sound and startle responses in herring shoals. *J. Mar. Biol. Assoc. United Kingdom* **61**, 851–869.
- Bolivar, V. J.** (2009). Intrasession and intersession habituation in mice: from inbred strain variability to linkage analysis. *Neurobiol. Learn. Mem.* **92**, 206–14.
- Boussard, A.** (1981). The reactions of roach (*Rutilus rutilus*) and rudd (*Scardinius erythrophthalmus*) to noises produced by high speed boating. In *Proceedings of 2nd British Freshwater Fisheries Conference* (ed. O'Hara, K. and Barr, C. D.), pp. 188–388. Liverpool: University of Liverpool.

Bouton, N., Slabbekoorn, H. and Hawkins, A. (2015). Hearing and water column use in North Sea fishes : a review to serve exploration of variation in exposure to vessel sounds among species and species groups. *IBL-report for TNO for the EU SONIC-project*.

Brandt, M. J., Diederichs, A., Betke, K. and Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Mar. Ecol. Prog. Ser.* **421**, 205–216.

Brewer, M. (2000). Research design and issues of validity. In *Handbook of research methods in social and personality psychology* (ed. Reis, H. and Judd, C.), pp. 3–16. Cambridge: Cambridge University Press.

Buscaino, G., Filiciotto, F., Buffa, G., Bellante, A., Di Stefano, V., Assenza, A., Fazio, F., Caola, G. and Mazzola, S. (2010). Impact of an acoustic stimulus on the motility and blood parameters of European sea bass (*Dicentrarchus labrax L.*) and gilthead sea bream (*Sparus aurata L.*). *Mar. Environ. Res.* **69**, 136–42.

Cachat, J., Stewart, A., Grossman, L., Gaikwad, S., Kadri, F., Chung, K. M., Wu, N., Wong, K., Roy, S., Suciu, C., et al. (2010). Measuring behavioral and endocrine responses to novelty stress in adult zebrafish. *Nat. Protoc.* **5**, 1786–99.

Cachat, J., Stewart, A., Utterback, E., Hart, P., Gaikwad, S., Wong, K., Kyzar, E., Wu, N. and Kalueff, A. V (2011). Three-dimensional neurophenotyping of adult zebrafish behavior. *PLoS One* **6**, e17597.

Calisi, R. M. and Bentley, G. E. (2009). Lab and field experiments: are they the same animal? *Horm. Behav.* **56**, 1–10.

Campbell, D. T. (1957). Factors relevant to the validity of experiments in social settings. *Psychol. Bull.* **54**, 297–312.

Casper, B. M., Popper, A. N., Matthews, F., Carlson, T. J. and Halvorsen, M. B. (2012). Recovery of Barotrauma Injuries in Chinook Salmon, *Oncorhynchus tshawytscha* from Exposure to Pile Driving Sound. *PLoS One* **7**, e39593.

Casper, B. M., Smith, M. E., Halvorsen, M. B., Sun, H., Carlson, T. J. and Popper, A. N. (2013a). Effects of exposure to pile driving sounds on fish inner ear tissues. *Comp. Biochem. Physiol. Part A Mol. Integr. Physiol.* **166**, 352–360.

Casper, B. M., Halvorsen, M. B., Matthews, F., Carlson, T. J. and Popper, A. N. (2013b). Recovery of barotrauma injuries resulting from exposure to pile driving sound in two sizes of hybrid striped bass. *PLoS One* **8**, e73844.

Cato, D. H., Noad, M. J., Dunlop, R. a., McCauley, R. D., Gales, N. J., Kent, C. P. S., Kniest, H., Paton, D., Jenner, K. C. S., Noad, J., Maggi, A. L., Parnum, I. M., Duncan, A. J. (2013). A study of the behavioural response of whales to the noise of seismic air guns: Design , methods and progress. *Acoust. Aust.* **41**, 88–97.

Bibliography

- Celi, M., Filiciotto, F., Maricchiolo, G., Genovese, L., Quinci, E. M., Maccarrone, V., Mazzola, S., Vazzana, M. and Buscaino, G.** (2015). Vessel noise pollution as a human threat to fish: assessment of the stress response in gilthead sea bream (*Sparus aurata*, Linnaeus 1758). *Fish Physiol. Biochem.* **42**, 1–11.
- Cerdá-Reverter, J. M., Zanuy, S., Carrillo, M. and Madrid, J. A.** (1998). Time-course studies on plasma glucose, insulin, and cortisol in sea bass (*Dicentrarchus labrax*) held under different photoperiodic regimes. *Physiol. Behav.* **64**, 245–250.
- Chan, A. A. Y.-H., Giraldo-Perez, P., Smith, S. and Blumstein, D. T.** (2010). Anthropogenic noise affects risk assessment and attention: the distracted prey hypothesis. *Biol. Lett.* **6**, 458–61.
- Chanin, S., Fryar, C., Varga, D., Raymond, J., Kyzar, E., Enriquez, J., Bagawandoss, S., Gaikwad, S., Roth, A., Pham, M., Zapolsky, I., Bruce, I., Hester, J., Green, J., Desmond, D., Stewart, A. M., Kalueff, A. V..** (2012). Assessing startle responses and their habituation in adult zebrafish. *Zebrafish Protoc. Neurobehav. Res. Neuromethods* **66**, 287–300.
- Codarin, A., Wysocki, L. E., Ladich, F. and Picciulin, M.** (2009). Effects of ambient and boat noise on hearing and communication in three fish species living in a marine protected area (Miramare, Italy). *Mar. Pollut. Bull.* **58**, 1880–1887.
- Conrad, J. L., Weinersmith, K. L., Brodin, T., Saltz, J. B. and Sih, A.** (2011). Behavioural syndromes in fishes: a review with implications for ecology and fisheries management. *J. Fish Biol.* **78**, 395–435.
- Davidson, J., Bebak, J. and Mazik, P.** (2009). The effects of aquaculture production noise on the growth, condition factor, feed conversion, and survival of rainbow trout, *Oncorhynchus mykiss*. *Aquaculture* **288**, 337–343.
- Davis, M.** (1970). Effects of interstimulus interval length and variability on startle-response habituation in the rat. *J. Comp. Physiol. Psychol.* **72**, 177–192.
- Davis, R. I., Qiu, W. and Hamernik, R. P.** (2009). Role of the kurtosis statistic in evaluating complex noise exposures for the protection of hearing. *Ear Hear.* **30**, 628–634.
- Dazey, E., McIntosh, B., Brown, S. and Dudzinski, K. M.** (2012). Assessment of underwater anthropogenic noise associated with construction activities in Bechers Bay, Santa Rosa Island, California. *J. Environ. Prot. (Irvine, Calif.)* **3**, 1286–1294.
- De Pedro, N., Guijarro, A. I., López-Patiño, M. A., Martínez-Álvarez, R. and Delgado, M. J.** (2005). Daily and seasonal variations in haematological and blood biochemical parameters in the tench, *Tinca tinca* Linnaeus, 1758. *Aquac. Res.* **36**, 1185–1196.
- Dickmeis, T.** (2009). Glucocorticoids and the circadian clock. *J. Endocrinol.* **200**, 3–22.

- Doksæter, L., Handegard, N. O., Godø, O. R., Kvadsheim, P. H. and Nordlund, N.** (2012). Behavior of captive herring exposed to naval sonar transmissions (1.0–1.6 kHz) throughout a yearly cycle. *J. Acoust. Soc. Am.* **131**, 1632–42.
- Domjan, M.** (2010). *The Principles of Learning and Behaviour*. 6th ed. Belmont, CA: Wadsworth, Cengage Learning.
- Eaton, R. C., Bombardieri, R. A. and Meyer, D. L.** (1977). The Mauthner-initiated startle response in teleost fish. *J. Exp. Biol.* **66**, 65–81.
- EIA** (2013). *International Energy Outlook 2013*. Washington.
- Eisenstein, E. M. and Eisenstein, D.** (2006). A behavioral homeostasis theory of habituation and sensitization: II. Further developments and predictions. *Rev. Neurosci.* **17**, 533–57.
- Eisenstein, E. M., Eisenstein, D. L., Sarma, J. S. M., Knapp, H. and Smith, J. C.** (2012). Some new speculative ideas about the “behavioral homeostasis theory” as to how the simple learned behaviors of habituation and sensitization improve organism survival throughout phylogeny. *Commun. Integr. Biol.* **5**, 233–239.
- Engeland, W. C. and Arnhold, M. M.** (2005). Neural circuitry in the regulation of adrenal corticosterone rhythmicity. *Endocrine* **28**, 325–332.
- Enger, P. S.** (1981). Frequency discrimination in teleosts – central or peripheral? In *Hearing and Sound Communication in Fishes* (ed. Tavolga, W. N., Popper, A. N. and Fay, R. R.), pp. 243–255. New York: Springer-Verlag.
- Fewtrell, J. L. and McCauley, R. D.** (2012). Impact of air gun noise on the behaviour of marine fish and squid. *Mar. Pollut. Bull.* **64**, 984–93.
- Filiciotto, F., Giacalone, V. M., Fazio, F., Buffa, G., Piccione, G., Maccarrone, V., Di Stefano, V., Mazzola, S. and Buscaino, G.** (2013). Effect of acoustic environment on gilthead sea bream (*Sparus aurata*): Sea and onshore aquaculture background noise. *Aquaculture* **414**, 36–45.
- FISHBIO** (2013). *Predation Study Report Don Pedro Project FERC No. 2299*.
- Frimodt, C.** (1995). *Illustrated multilingual guide to the world's commercial warmwater fish*. Osney Mead, Oxford: Wiley-Blackwell.
- Gerlotto, F. and Fréon, P.** (1992). Some elements on vertical avoidance of fish schools to a vessel during acoustic surveys. *Fish. Res.* **14**, 251–259.
- Grissom, N. and Bhatnagar, S.** (2009). Habituation to repeated stress: get used to it. *Neurobiol. Learn. Mem.* **92**, 215–24.
- Groves, P. and Thompson, R.** (1970). Habituation: a dual-process theory. *Psychol. Rev.* **77**, 419–450.

Bibliography

- Halvorsen, M. B., Casper, B. M., Woodley, C. M., Carlson, T. J. and Popper, A. N.** (2012a). Threshold for onset of injury in Chinook salmon from exposure to impulsive pile driving sounds. *PLoS One* **7**, e38968.
- Halvorsen, M. B., Casper, B. M., Matthews, F., Carlson, T. J. and Popper, A. N.** (2012b). Effects of exposure to pile-driving sounds on the lake sturgeon, Nile tilapia and hogchoker. *Proc. R. Soc. B Biol. Sci.* **279**, 4705–14.
- Handegard, N. O. and Tjøstheim, D.** (2005). When fish meet a trawling vessel: examining the behaviour of gadoids using a free-floating buoy and acoustic split-beam tracking. *Can. J. Fish. Aquat. Sci.* **62**, 2409–2422.
- Handegard, N. O., Michalsen, K. and Tjøstheim, D.** (2003). Avoidance behaviour in cod (*Gadus morhua*) to a bottom-trawling vessel. *Aquat. Living Resour.* **16**, 265–270.
- Handegard, N. O., Tronstad, T. V. and Hovem, J. M.** (2013). Evaluating the effect of seismic surveys on fish—the efficacy of different exposure metrics to explain disturbance. *Can. J. Fish. Aquat. Sci.* **70**, 1271–1277.
- Hastings, M. C. and Popper, A. N.** (2005). *Effects of sound on fish*. Sacramento.
- Hastings, M. C., Popper, A. N., Finneran, J. J. and Lanford, P. J.** (1996). Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish *Astronotus ocellatus*. *J. Acoust. Soc. Am.* **99**, 1759–66.
- Hawkins, A. and Johnstone, A.** (1978). The hearing of the Atlantic salmon, *Salmo salar*. *J. Fish Biol.* **13**, 655–673.
- Hawkins, A. D., Pembroke, A. E. and Popper, A. N.** (2014a). Information gaps in understanding the effects of noise on fishes and invertebrates. *Rev. Fish Biol. Fish.* **25**, 39–64.
- Hawkins, A. D., Roberts, L. and Cheesman, S.** (2014b). Responses of free-living coastal pelagic fish to impulsive sounds. *J. Acoust. Soc. Am.* **135**, 3101–3116.
- Hirst, A. and Rodhouse, P.** (2000). Impacts of geophysical seismic surveying on fishing success. *Rev. Fish Biol. Fish.* **10**, 113–118.
- Hoare, D. J., Couzin, I. D., Godin, J.-G. J. and Krause, J.** (2004). Context-dependent group size choice in fish. *Anim. Behav.* **67**, 155–164.
- Holt, D. E. and Johnston, C. E.** (2009). Signaling without the risk of illegitimate receivers: do predators respond to the acoustic signals of Cyprinella (Cyprinidae)? *Environ. Biol. Fishes* **84**, 347–357.
- Holt, D. E. and Johnston, C. E.** (2011). Can you hear the dinner bell? Response of cyprinid fishes to environmental acoustic cues. *Anim. Behav.* **82**, 529–534.

- Hüseyin, Ö. S. and Ainslie, M. A.** (2014). A depth-dependent formula for shallow water propagation. *J. Acoust. Soc. Am.* **136**, 573–582.
- ICES** (2015). *ICES Advice on fishing opportunities, catch, and effort. Celtic Seas and Greater North Sea Ecoregions. Book 5.*
- Israeli-Weinstein, D. and Kimmel, E.** (1998). Behavioral response of carp (*Cyprinus carpio*) to ammonia stress. *Aquaculture* **165**, 81–93.
- JNCC** (2010). JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys.
- Kastelein, R. A., Heul, S. Van Der, Verboom, W. C., Jennings, N., Veen, J. Van Der and de Haan, D.** (2008). Startle response of captive North Sea fish species to underwater tones between 0.1 and 64 kHz. *Mar. Environ. Res.* **65**, 369–77.
- Kennedy, E. V., Holderied, M. W., Mair, J. M., Guzman, H. M. and Simpson, S. D.** (2010). Spatial patterns in reef-generated noise relate to habitats and communities: Evidence from a Panamanian case study. *J. Exp. Mar. Bio. Ecol.* **395**, 85–92.
- Knudsen, V., Alford, R. and Emling, J.** (1948). Underwater ambient noise. *J. Mar. Res.* **7**, 410–429.
- Koeck, B., Pastor, J., Saragoni, G., Dalias, N., Payrot, J. and Lenfant, P.** (2014). Diel and seasonal movement pattern of the dusky grouper *Epinephelus marginatus* inside a marine reserve. *Mar. Environ. Res.* **94**, 38–47.
- Koolhaas, J. M., Bartolomucci, a, Buwalda, B., de Boer, S. F., Flügge, G., Korte, S. M., Meerlo, P., Murison, R., Olivier, B., Palanza, P., Richter-Levin, G., Sgoifo, A., Steimer, T., Stiedl, O., van Dijk, G., Wöhr, M., Fuchs, E.** (2011). Stress revisited: a critical evaluation of the stress concept. *Neurosci. Biobehav. Rev.* **35**, 1291–301.
- Kühn, E. R., Corneillie, S. and Ollevier, F.** (1986). Circadian variations in plasma osmolality , electrolytes , and cortisol in Carp (*Cyprinus carpio*). *Gen. Comp. Endocrinol.* **61**, 459–468.
- Kuwada, H., Masuda, R., Shiozawa, S., Kogane, T., Imaizumi, K. and Tsukamoto, K.** (2000). Effect of fish size, handling stresses and training procedure on the swimming behavior of hatchery-reared striped jack: implications for stock enhancement. *Aquaculture* **185**, 245–256.
- Ladich, F.** (1997). Agonistic behaviour and significance of sounds in vocalizing fish. *Mar. Freshw. Behav. Physiol.* **29**, 87–108.
- Ladich, F.** (2008). Sound communication in fishes and the influence of ambient and anthropogenic noise. *Bioacoustics* **17**, 37–41.

Bibliography

- Lankford, S. E., Adams, T. E. and Cech, J. J.** (2003). Time of day and water temperature modify the physiological stress response in green sturgeon, *Acipenser medirostris*. *Comp. Biochem. Physiol. A. Mol. Integr. Physiol.* **135**, 291–302.
- Leopold, M. F. and Camphuysen, K. C. J.** (2008). *Did the pile driving during the construction of the Offshore Wind Farm Egmond aan Zee, the Netherlands, impact porpoises? (Report no: C091/09)*. IJmuiden.
- Lepage, O., Øverli, Ø., Petersson, E., Järvi, T. and Winberg, S.** (2000). Differential stress coping in wild and domesticated sea trout. *Brain. Behav. Evol.* **56**, 259–268.
- Løkkeborg, S., Ona, E., Vold, A., Salthaug, A. and Jech, J. M.** (2012). Sounds from seismic air guns: gear- and species-specific effects on catch rates and fish distribution. *Can. J. Fish. Aquat. Sci.* **69**, 1278–1291.
- López-Olmeda, J. F., Blanco-Vives, B., Pujante, I. M., Wunderink, Y. S., Mancera, J. M. and Sánchez-Vázquez, F. J.** (2013). Daily rhythms in the hypothalamus-pituitary-interrenal axis and acute stress responses in a teleost flatfish, *Solea senegalensis*. *Chronobiol. Int.* **30**, 530–9.
- Lovell, J. M.** (2003). *The hearing abilities of the bass, Dicentrarchus labrax. Technical report commissioned by ARIA Marine Ltd. for the European Commission Fifth Framework Programme. Project Reference: Q5AW-CT-2001-01896*.
- Luca, R. M. and Gerlai, R.** (2012). In search of optimal fear inducing stimuli: Differential behavioral responses to computer animated images in zebrafish. *Behav. Brain Res.* **226**, 66–76.
- Manuel, R., Gorissen, M., Zethof, J., Ebbesson, L. O. E., van de Vis, H., Flik, G. and van den Bos, R.** (2014). Unpredictable chronic stress decreases inhibitory avoidance learning in Tuebingen long-fin zebrafish: stronger effects in the resting phase than in the active phase. *J. Exp. Biol.* **217**, 3919–28.
- Marvit, P. and Crawford, J. D.** (2000). Auditory discrimination in a sound-producing electric fish (*Pollimyrus*): tone frequency and click-rate difference detection. *J. Acoust. Soc. Am.* **108**, 1819–25.
- Matuschek, R. and Betke, K.** (2009). Measurements of construction noise during pile driving of offshore research platforms and wind farms. In *NAG/DAGA International Conference on Acoustics 2009* (ed. Boone, M.), pp. 262–265. Rotterdam: Curran Associates, Inc.
- Maximino, C., de Brito, T. M., da Silva Batista, A. W., Herculano, A. M., Morato, S. and Gouveia Jr, A.** (2010). Measuring anxiety in zebrafish: a critical review. *Behav. Brain Res.* **214**, 157–71.
- McCauley, R., Fewtrell, J., Duncan, A. J., Jenner, C., Jenner, M.-N., Penrose, J. D., Prince, R. I. T., Adhitya, A., Murdoch, J. and McCabe, K.** (2000). Marine seismic surveys: a study of environmental implications. *Aust. Pet. Prod. Explor. Assoc. J.* 692–708.

- McCauley, R. D., Fewtrell, J. and Popper, A. N.** (2003). High intensity anthropogenic sound damages fish ears. *J. Acoust. Soc. Am.* **113**, 638–642.
- McLaughlin, K. E. and Kunc, H. P.** (2015). Changes in the acoustic environment alter the foraging and sheltering behaviour of the cichlid *Amititlania nigrofasciata*. *Behav. Processes* **116**, 75–79.
- Miller, N. and Gerlai, R.** (2012). From schooling to shoaling: patterns of collective motion in zebrafish (*Danio rerio*). *PLoS One* **7**, e48865.
- Mitsunaga, Y., Endo, C. and Babaran, R. P.** (2013). Schooling behavior of juvenile yellowfin tuna *Thunnus albacares* around a fish aggregating device (FAD) in the Philippines. *Aquat. Living Resour.* **84**, 79–84.
- Montoya, A., López-Olmeda, J. F., Garayzar, A. B. S. and Sánchez-Vázquez, F. J.** (2010). Synchronization of daily rhythms of locomotor activity and plasma glucose, cortisol and thyroid hormones to feeding in Gilthead seabream (*Sparus aurata*) under a light-dark cycle. *Physiol. Behav.* **101**, 101–7.
- Nedelec, S. L., Simpson, S. D., Morley, E. L., Nedelec, B. and Radford, A. N.** (2015). Impacts of regular and random noise on the behaviour, growth and development of larval Atlantic cod (*Gadus morhua*). *Proc. R. Soc. B Biol. Sci.* **282**, 20151943.
- Nelson, D. and Johnson, R.** (1972). Acoustic attraction of Pacific reef sharks: effect of pulse intermittency and variability. *Comp. Biochem. Physiol. Part A Physiol.* **42**, 85–95.
- Neo, Y. Y., Seitz, J., Kastelein, R. A., Winter, H. V., ten Cate, C. and Slabbekoorn, H.** (2014). Temporal structure of sound affects behavioural recovery from noise impact in European seabass. *Biol. Conserv.* **178**, 65–73.
- Neo, Y. Y., Ufkes, E., Kastelein, R. A., Winter, H. V., ten Cate, C. and Slabbekoorn, H.** (2015a). Impulsive sounds change European seabass swimming patterns: Influence of pulse repetition interval. *Mar. Pollut. Bull.* **97**, 111–117.
- Neo, Y. Y., Parie, L., Bakker, F., Snelderwaard, P., Tudorache, C., Schaaf, M. and Slabbekoorn, H.** (2015b). Behavioral changes in response to sound exposure and no spatial avoidance of noisy conditions in captive zebrafish. *Front. Behav. Neurosci.* **9**, 1–11.
- Normandeau Associates** (2012). *Effects of noise on fish, fisheries, and invertebrates in the U.S. Atlantic and Arctic from energy industry sound-generating activities*.
- Nøttestad, L. and Axelsen, B.** (1999). Herring schooling manoeuvres in response to killer whale attacks. *Can. J. Zool.* **77**, 1540–1546.
- Oldfield, R. G.** (2011). Aggression and welfare in a common aquarium fish, the Midas Cichlid. *J. Appl. Anim. Welf. Sci.* **14**, 340–360.

Bibliography

- Oliveira, C. C. V., Aparício, R., Blanco-Vives, B., Chereguini, O., Martín, I. and Javier Sánchez-Vazquez, F.** (2013). Endocrine (plasma cortisol and glucose) and behavioral (locomotor and self-feeding activity) circadian rhythms in Senegalese sole (*Solea senegalensis* Kaup 1858) exposed to light/dark cycles or constant light. *Fish Physiol. Biochem.* **39**, 479–87.
- Parvulescu, A.** (1967). The acoustics of small tanks. In *Marine Bio-Acoustics Vol. 2* (ed. Tavolga, W. N.), pp. 7–13. London: Pergamon Press.
- Pavlidis, M., Greenwood, L., Paalavuo, M., Mölsä, H. and Laitinen, J. T.** (1999). The effect of photoperiod on diel rhythms in serum melatonin, cortisol, glucose, and electrolytes in the common dentex, *Dentex dentex*. *Gen. Comp. Endocrinol.* **113**, 240–50.
- Payne, N. L., van der Meulen, D. E., Suthers, I. M., Gray, C. A. and Taylor, M. D.** (2015). Foraging intensity of wild mullet *Argyrosomus japonicus* decreases with increasing anthropogenic disturbance. *Mar. Biol.* **162**, 539–546.
- Pearson, W. H., Skalski, J. R. and Malme, C. I.** (1992). Effects of sounds from a geophysical survey device on behavior of captive rockfish (*Sebastes spp.*). *Can. J. Fish. Aquat. Sci.* **49**, 1343–1356.
- Picciulin, M., Sebastianutto, L., Codarin, A., Farina, A. and Ferrero, E. A.** (2010). In situ behavioural responses to boat noise exposure of *Gobius cruentatus* (Gmelin, 1789; fam. Gobiidae) and *Chromis chromis* (Linnaeus, 1758; fam. Pomacentridae) living in a Marine Protected Area. *J. Exp. Mar. Bio. Ecol.* **386**, 125–132.
- Planas, J., Gutierrez, J., Fernandez, J., Carrillo, M. and Canals, P.** (1990). Annual and daily variations of plasma cortisol in sea bass, *Dicentrarchus labrax* L. *Aquaculture* **91**, 171–178.
- Polakof, S., Ceinos, R. M., Fernandez-Duran, B., Miguez, J. M. and Soengas, J. L.** (2007). Daily changes in parameters of energy metabolism in brain of rainbow trout: Dependence on feeding. *Comp. Biochem. Physiol. a-Molecular Integr. Physiol.* **146**, 265–273.
- Popper, A. N. and Fay, R. R.** (2011). Rethinking sound detection by fishes. *Hear. Res.* **273**, 25–36.
- Popper, A. N. and Hastings, M. C.** (2009a). The effects of human-generated sound on fish. *Integr. Zool.* **4**, 43–52.
- Popper, A. N. and Hastings, M. C.** (2009b). The effects of anthropogenic sources of sound on fishes. *J. Fish Biol.* **75**, 455–89.
- Popper, A. N. and Hawkins, A.** (2011). *The effects of noise on aquatic life*. New York: Springer Science+Business Media.
- Popper, A. N., Smith, M. E., Cott, P. A., Hanna, B. W., MacGillivray, A. O., Austin, M. E. and Mann, D. A.** (2005). Effects of exposure to seismic airgun use on hearing of three fish species. *J. Acoust. Soc. Am.* **117**, 3958–3971.

- Popper, A. N., Halvorsen, M. B., Kane, A., Miller, D. L., Smith, M. E., Song, J., Stein, P. and Wysocki, L. E.** (2007). The effects of high-intensity, low-frequency active sonar on rainbow trout. *J. Acoust. Soc. Am.* **122**, 623–35.
- Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., Coombs, S., Ellison, W. T., Gentry, R. L., Halvorsen, M. B., Løkkeborg, S., Rogers, P. H., Southall, B. L., Zedde, D. G., Tavolga, W. N.** (2014). *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*.
- Purser, J. and Radford, A. N.** (2011). Acoustic noise induces attention shifts and reduces foraging performance in three-spined sticklebacks (*Gasterosteus aculeatus*). *PLoS One* **6**, e17478.
- Radford, C. A., Stanley, J. A., Simpson, S. D. and Jeffs, A. G.** (2011). Juvenile coral reef fish use sound to locate habitats. *Coral Reefs* **30**, 295–305.
- Radford, C. A., Montgomery, J. C., Caiger, P. and Higgs, D. M.** (2012). Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. *J. Exp. Biol.* **215**, 3429–3435.
- Radford, A. N., Kerridge, E. and Simpson, S. D.** (2014). Acoustic communication in a noisy world: can fish compete with anthropogenic noise? *Behav. Ecol.* **25**, 1022–1030.
- Rankin, C. H. and Broster, B. S.** (1992). Factors affecting habituation and recovery from habituation in the nematode *Caenorhabditis elegans*. *Behav. Neurosci.* **106**, 239–49.
- Rankin, C. H., Abrams, T., Barry, R. J., Bhatnagar, S., Clayton, D. F., Colombo, J., Coppola, G., Geyer, M. a, Glanzman, D. L., Marsland, S., et al.** (2009). Habituation revisited: an updated and revised description of the behavioral characteristics of habituation. *Neurobiol. Learn. Mem.* **92**, 135–8.
- Robertis, A. De and Handegard, N. O.** (2013). Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review. *ICES J. Mar. Sci.* **70**, 34–45.
- Rossington, K., Benson, T., Lepper, P. and Jones, D.** (2013). Eco-hydro-acoustic modeling and its use as an EIA tool. *Mar. Pollut. Bull.* **75**, 235–243.
- Samson, J. E., Mooney, T. A., Gussekloo, S. W. S. and Hanlon, R. T.** (2014). Graded behavioral responses and habituation to sound in the common cuttlefish, *Sepia officinalis*. *J. Exp. Biol.* **217**, 4347–4355.
- Santulli, A., Modica, A., Messina, C., Ceffa, L., Curatolo, A., Rivas, G., Fabi, G. and D'Amelio, V.** (1999). Biochemical responses of European sea bass (*Dicentrarchus labrax L.*) to the stress induced by off shore experimental seismic prospecting. *Mar. Pollut. Bull.* **38**, 1105–1114.

Bibliography

- Sarà, G., Dean, J., D'Amato, D., Buscaino, G., Oliveri, A., Genovese, S., Ferro, S., Buffa, G., Martire, M. and Mazzola, S.** (2007). Effect of boat noise on the behaviour of bluefin tuna *Thunnus thynnus* in the Mediterranean Sea. *Mar. Ecol. Prog. Ser.* **331**, 243–253.
- Scholik, A. and Yan, H.** (2001). Effects of underwater noise on auditory sensitivity of a cyprinid fish. *Hear. Res.* **152**, 17–24.
- Sebastianutto, L., Picciulin, M., Costantini, M. and Ferrero, E. A.** (2011). How boat noise affects an ecologically crucial behaviour: the case of territoriality in *Gobius cruentatus* (Gobiidae). *Environ. Biol. Fishes* **92**, 207–215.
- Sertlek, H. Ö., Aarts, G., Brasseur, S., Slabbekoorn, H., Ten Cate, C., von Benda-Beckmann, A. M. and Ainslie, M. A.** (2016). Mapping underwater sound in the Dutch part of the North Sea. *Adv. Exp. Med. Biol.* **875**, 1001–6.
- Shafiei Sabet, S., Neo, Y. Y. and Slabbekoorn, H.** (2015). The effect of temporal variation in experimental noise exposure on swimming and foraging behaviour of captive zebrafish. *Anim. Behav.* 49–60.
- Silva, P. I. M., Martins, C. I. M., Engrola, S., Marino, G., Øverli, Ø. and Conceicao, L. E. C.** (2010). Individual differences in cortisol levels and behaviour of Senegalese sole (*Solea senegalensis*) juveniles: evidence for coping styles. *Appl. Anim. Behav. Sci.* **124**, 75–81.
- Simpson, S. D., Meekan, M. G., McCauley, R. D. and Jeffs, A.** (2004). Attraction of settlement-stage coral reef fishes to reef noise. *Mar. Ecol. Prog. Ser.* **276**, 263–268.
- Simpson, S. D., Meekan, M., Montgomery, J., McCauley, R. and Jeffs, A.** (2005). Homeward sound. *Science* **308**, 221.
- Simpson, S. D., Purser, J. and Radford, A. N.** (2014). Anthropogenic noise compromises antipredator behaviour in European eels. *Glob. Chang. Biol.* **21**, 586–593.
- Skilbrei, O. and Holst, J.** (2009). Vertical movements of “escaped” farmed Atlantic salmon (*Salmo salar* L.)—a simulation study in a western Norwegian fjord. *ICES J. Mar. Sci.* **66**, 278–288.
- Slabbekoorn, H.** (2012). The complexity of noise impact assessments: From birdsong to fish behavior. In *The Effects of Noise on Aquatic Life* (ed. Popper, A. N. and Hawkins, A.), pp. 497–500. Springer Science+Business Media, LLC.
- Slabbekoorn, H.** (2014). Aiming for progress in understanding underwater noise impact on fish: complementary need for indoor and outdoor studies. In *The effects of noise on aquatic life, Budapest Conference Proceedings* (ed. Popper, A. N. and Hawkins, A. D.), Elsevier.
- Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C. and Popper, A. N.** (2010). A noisy spring: the impact of globally rising underwater sound levels on fish. *Trends Ecol. Evol.* **25**, 419–27.

- Slotte, A., Hansen, K., Dalen, J. and Ona, E.** (2004). Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. *Fish. Res.* **67**, 143–150.
- Smith, M. E., Kane, A. S. and Popper, A. N.** (2004a). Noise-induced stress response and hearing loss in goldfish (*Carassius auratus*). *J. Exp. Biol.* **207**, 427–435.
- Smith, M. E., Kane, A. S. and Popper, A. N.** (2004b). Acoustical stress and hearing sensitivity in fishes: does the linear threshold shift hypothesis hold water? *J. Exp. Biol.* **207**, 3591–602.
- Speedie, N. and Gerlai, R.** (2008). Alarm substance induced behavioral responses in zebrafish (*Danio rerio*). *Behav. Brain Res.* **188**, 168–77.
- Stadler, J. H. and Woodbury, D. P.** (2009). Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria. In *38th International Congress and Exposition on Noise Control Engineering 2009 (INTER-NOISE 2009)* (ed. Bolton, J. S.), pp. 3580–3587. Ottawa, Ontario, Canada: Curran Associates, Inc.
- Thompson, R. and Spencer, W.** (1966). Habituation: a model phenomenon for the study of neuronal substrates of behavior. *Psychol. Rev.* **73**, 16–43.
- Thomsen, F., Mueller-Blenkle, C., Gill, A., Metcalfe, J., McGregor, P. K., Bendall, V., Andersson, M. H., Sigray, P. and Wood, D.** (2012). Effects of pile driving on the behavior of cod and sole. *Adv. Exp. Med. Biol.* **730**, 387–388.
- Vasconcelos, R. O., Amorim, M. C. P. and Ladich, F.** (2007). Effects of ship noise on the detectability of communication signals in the Lusitanian toadfish. *J. Exp. Biol.* **210**, 2104–12.
- Vera, L. M., Montoya, A., Pujante, I. M., Pérez-Sánchez, J., Caldúch-Giner, J. A., Mancera, J. M., Moliner, J. and Sánchez-Vázquez, F. J.** (2014). Acute stress response in gilthead sea bream (*Sparus aurata* L.) is time-of-day dependent: Physiological and oxidative stress indicators. *Chronobiol. Int.* **31**, 1051–61.
- Verzijden, M. N., van Heusden, J., Bouton, N., Witte, F., ten Cate, C. and Slabbekoorn, H.** (2010). Sounds of male Lake Victoria cichlids vary within and between species and affect female mate preferences. *Behav. Ecol.* **21**, 548–555.
- Videler, J. and Wardle, C.** (1991). Fish swimming stride by stride: speed limits and endurance. *Rev. Fish Biol. Fish.* **40**, 23–40.
- Voellmy, I. K., Purser, J., Simpson, S. D. and Radford, A. N.** (2014a). Increased noise levels have different impacts on the anti-predator behaviour of two sympatric fish species. *PLoS One* **9**, e102946.
- Voellmy, I. K., Purser, J., Flynn, D., Kennedy, P., Simpson, S. D. and Radford, A. N.** (2014b). Acoustic noise reduces foraging success in two sympatric fish species via different mechanisms. *Anim. Behav.* **89**, 191–198.

Bibliography

- Von Benda-Beckmann, A. M., Wensveen, P. J., Kvadsheim, P. H., Lam, F. P. A., Miller, P. J. O., Tyack, P. L. and Ainslie, M. A.** (2014). Modeling effectiveness of gradual increases in source level to mitigate effects of sonar on marine mammals. *Conserv. Biol.* **28**, 119–128.
- Ward, D., Morison, F., Morrissey, E., Jenks, K. and Watson, W. H.** (2011). Evidence that potential fish predators elicit the production of carapace vibrations by the American lobster. *J. Exp. Biol.* **214**, 2641–8.
- Wardle, C. S., Carter, T. J., Urquhart, G. G., Johnstone, A. D. F., Ziolkowski, A. M., Hampson, G. and Mackie, D.** (2001). Effects of seismic air guns on marine fish. *Cont. Shelf Res.* **21**, 1005–1027.
- Weilgart, L. S.** (2007). The impacts of anthropogenic ocean noise on cetaceans and implications for management. *Can. J. Zool.* **85**, 1091–1116.
- Wilson, B. and Dill, L. M.** (2002). Pacific herring respond to simulated odontocete echolocation sounds. *Can. J. Fish. Aquat. Sci.* **59**, 542–553.
- Wong, K., Elegante, M., Bartels, B., Elkhayat, S., Tien, D., Roy, S., Goodspeed, J., Suciu, C., Tan, J., Grimes, C., Chung, A., Rosenberg, M., Gaikwad, S., Denmark, A., Jackson, A., Kadri, F., Chung, K. M., Stewart, A., Gilder, T., Beeson, E., Zapolsky, I., Wu, N., Cachat, J., Kalueff, A. V.** (2010). Analyzing habituation responses to novelty in zebrafish (*Danio rerio*). *Behav. Brain Res.* **208**, 450–7.
- Woodbury, D. P. and Stadler, J. H.** (2008). A proposed method to assess physical injury to fishes from underwater sound produced during pile driving. *Bioacoustics Int. J. Anim. Sound its Rec.* **17**, 289–291.
- Wysocki, L. and Ladich, F.** (2002). Can fishes resolve temporal characteristics of sounds? New insights using auditory brainstem responses. *Hear. Res.* **169**, 36–46.
- Wysocki, L. E. and Ladich, F.** (2005). Effects of noise exposure on click detection and the temporal resolution ability of the goldfish auditory system. *Hear. Res.* **201**, 27–36.
- Wysocki, L. E., Dittami, J. P. and Ladich, F.** (2006). Ship noise and cortisol secretion in European freshwater fishes. *Biol. Conserv.* **128**, 501–508.
- Zhdanova, I. V** (2006). Sleep in zebrafish. *Zebrafish* **3**, 215–226.
- Zhdanova, I. V.** (2011). Sleep and its regulation in zebrafish. *Rev. Neurosci.* **22**, 27–36.

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Neo YY, Parie L, Bakker F, Snelderwaard P, Tudorache C, Schaaf M & Slabbekoorn H. 2015. Behavioral changes in response to sound exposure and no spatial avoidance of noisy conditions in captive zebrafish. *Frontier of Behavioural Neuroscience* **9**: 1-11.

Neo YY, Hubert J, Bolle L, Winter HV, ten Cate C & Slabbekoorn H, 2016. Sound exposure changes European seabass behaviour in a large outdoor floating pen: effects of temporal structure and a ramp-up procedure. *Environmental Pollution* **214**: 26-34.

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