Electronic supplementary material 1 (methods and literature list) to Svensson and Kvarnemo (2023). *How sexual and natural selection interact and shape the evolution of nests and nesting behaviour in fishes*. Phil. Trans. R. Soc. B. (10.1098/rstb.2022.0139)

Methods

Included families

Table S1 shows the families from which we have found published studies on nest building. Alternative names are indicated and included with an OR in our search.

Table S1. Ray –finned fish families with published descriptions of nest building

Amiidae	Cottidae	Loricariidae
Anabantidae	Cryonotothenioid icefish families	Mormyridae
Aulorhynchidae OR Hypoptychidae	Cyclopteridae	Opistognathidae
Bagridae	Cyprinidae OR Leuciscidae	Osphronemidae
Batrachoididae	Cyprinodontidae	Osteoglossidae
Blenniidae	Erythrinidae	Pholidichthyidae
Callichthyidae	Gasterosteidae	Plotosidae
Centrarchidae	Gobiidae OR Oxudercidae	Pomacentridae
Channidae	Gymnotidae	Salmonidae
Characidae	Hypoptychidae	Synbranchidae
Cichlidae	Ictaluridae	Tetraodontidae
Claroteidae	Labridae	Zoarcidae (only oviparous species)

We started our search focusing on all ray finned fish (Actinopterygii) families identified as nest builders in Table 1 in Bessa et al. [1]. In addition to that list, we included families that we knew contain nest building species, or sister families that contain nest builders in our search, and we also exploratorily searched for nest building fish. Based on this effort, the following families were added to Table S1, all featuring published descriptions of nest building or nests, Mormyridae [2, 3], Pholidichthyidae [4], Cottidae [5], Opistognathidae [6] and the cryonotothenioid icefish families (Artedidraconidae, Bathydraconidae, Channichthyidae, Harpagiferidae and Nototheniidae) [7].

The following families were evaluated without finding any detailed description on nest building: Bathymasteridae, Botiidae, Butidae, Cobitidae, Cryptacanthodidae, Eleotridae, Eulophiidae, Milyeringidae, Odacidae, Odontobitidae, Ptilichthyidae, Rhyacichthidae, Scaridae, Scytalinidae, Stichaeidae, Thalasseleotrididae and Zaproridae. Anarhichadidae and Pholidae use holes and cavities as breeding sites [8-10], but we have not found mentioning of actual nest building. Hence, neither of these families are included in Table S1.

In several families of catfishes (Siluriformes), despite being reported as nest-builders in [1] with a reference to [11], nest building appears to be absent or the published records are very limited. We found no published record of nest building in Aspredinidae (OR Bunocephalinae) and Pimelodidae. We did not find any detailed scientific description of nest building behaviour of Ariidae, Clariidae or Heteropneustidae. One species each of Ariidae, Clariidae and Doradidae are mentioned as nest builders in Breder and Rosen [9] but we have not been able to confirm this with more recent observations. Similarly, Heteropneustidae is mentioned as nest builder in Breeder and Rosen [9], as well as in the hobbyist aquarium literature [12], however, without being substantiated in more recent scientific publications. Hence, neither of these catfish families are included in Table S1.

Finally, the toothcarp *Fundulus heteroclitus* (Cyprinodontiformes, Fundulidae) is mentioned as a nest builder in [1], in the text regarding Cyprinidae. That is, however, probably an error and the text refers to another species.

Search approach for sexually selected nest building

We searched Clarivate Web of Science (Search in: All Databases. Collections: All) for each family mentioned in the previous section, with the taxonomic suffix replaced with "*". In each search we also included several common genus names with the suffix replaced by "*", as well as established common names, with OR in-between. For example, we searched for studies on gouramis within Osphronemidae using the search string "Osphronemid* OR Betta OR gouram* OR Belontid* OR Colisa OR Thricho* OR Macropod*". We thereafter refined the search using the strings "nest* OR *nest OR bower* OR *bower" and ""sexual selection" OR "mate choice" OR "female choice" OR "male choice" OR "mate competition" OR "male-male competition"". All articles found by these searches were evaluated. However, for many families there were very few articles and we therefore evaluated the articles from the two search strings separately, and in some cases used alternative terms to nest, such as "burrow" or "redd". For the families with few articles in Web of Science we made additional searches in Google scholar and the books by Breeder and Rosen [9], Ross [13, 14] as well as Riel and Baensch's Aquarien Atlas series [15, 16]. We also used Google searches for hobbyist aquarium and governmental web pages, and Wikipedia and references therein e.g. for Amiidae to find books and book chapters where nesting behaviour were described. We ended up with 403 journal articles, governmental reports, books and book chapters (listed in the literature list below), which were more thoroughly reviewed for relevant content.

Inclusion criteria

Given the nature of our review (being neither a meta-analysis, nor a book), not every record of nest-building in fin-rayed fish could be included. Instead, we allowed ourselves to select examples that we felt served a purpose. Priority was given to experimental studies and field studies with a focus on sexual selection, mate choice and mate competition in relation to a built nest. However, as we aimed for a systematically broad review, our inclusion criteria were stricter for well-studied groups such as Gobiidae, *Gasterosteus* spp. and Cichlidae, than for those systematic groups where few studies on nest building exist. In addition, we also aimed to have a broad review covering all types of nests and therefore, inclusion criteria were less strict for unique nest constructions. For the latter two, links to sexual selections were brought forward as hypothetical and discussed in relation to available information.

Non-ray finned fish examples

Our review also includes a section on evidence of sexually selected nest-building in other taxa than the ray-finned fishes. Taxonomic groups evaluated for inclusion as examples were lampreys, lungfishes, avian and non-avian dinosaurs, mammals, amphibians and arthropods. Specifics searches were made within frogs, birds, dinosaurs, reptiles, crocodiles, snakes, lizards, insects, arachnids, spiders and crustaceans. We used the same search strings as above,

but also included e.g. “burrow” and “lair” in the strings. Criteria for being included in the review were strict and based on research on sexual selection, mate choice or mate competition, as well as resemblance with ray finned fishes and a systematically broad review. In our paper, we have given priority to review articles and cases that illustrate the potential for sexually selected nest building. We have included examples from birds (Aves), frogs (Amphibia), fiddler crabs (Crustacea), dung beetles (Coleoptera, Insecta), harvestmen (Opiliones, Archnidea) and wolf spiders (Araneae, Archnidea). For the sake of brevity, however, we did not include examples of published research on nest building behaviour in horseshoe crabs (Limulidae, Xiphosura), lampreys (Agnatha), lungfishes (Dipnoi), mammals (Mammalia) or wasps (Hymenoptera, Insecta), although they do exist. Overall, our impression is that sexually selected nest building is markedly less well investigated in the published research in these taxa, compared to in the ray-finned fish.

Scientific names and species identification

In the review, we use the valid scientific names of fish species provided by Eschmeyer's Catalog of Fishes [17]. We have also paid attention to which study species that were the same although published under different names when we reviewed the literature for relevant content. Here, we go through the most notable changes, although many more species in the literature list below have changed names. *Padogobius martensii* (spelled *P. martensi*) is a junior synonym of *Padogobius bonelli* and the latter is thus used in the text. For the (northern) longear sunfish *Lepomis megalotis peltastes* we use the northern sunfish *Lepomis peltastes*. *Gobiosculus flavescens* is nowadays placed in *Pomatoschistus* whereas *Lamprologus multifasiatus* has been removed from *Neolamprologus* and thus returned to its original genus. We therefore use *P. flavescens* and *L. multifasciatus* in the text. The present valid name for the cited population of *Archocentrus nigrofasciatu*s is *Amatitlania siquia*. The valid name for *Colisa* is *Trichogaster* and the valid name for the species that were former placed in *Trichogaster* is *Trichopodus* which causes some confusion. Among the non-fish species, there have also been changes. *Austruca annulipes* was previously *Uca annulipes* and *Quindina albomarginis* was previously *Zygopachylus albomarginis*. The latter is now placed in the family Nomoclastidae.

Furthermore, we have found one misidentification. *Bujurquina vittata* is a larvophilic mouth brooder that lays its eggs on leaves (*Aequidens paraguayensis* = *B. vittata*) [18]. All it’s congeners for which breeding behaviour is known are also larvofilic moutbrooders [19, 20]. However, in one publication [21], the breeding behaviour of *Aequidens vittatus* (= *B. vittata*) in nature was described to include not just spawning on leaves, but also the parents moving the larvae between pits, and without mouth-brooding them after they hatched [21]. Furthermore, there are no reported *Bujurquina* species in the area where the study took place [22]. Based on these discrepancies and the fish fauna documented at the study site [22] we conclude that the studied cichlid probably was *Krobia guianensis*. Thus, we refer to the species as misidentified and probably a *Krobia* in our review. The cichlasomatin cichlids of the genera *Andinoacara*, *Bujurquina* and *Krobia* were all referred to as *Aequidens* in the literature before the revision of *Aequidens*.

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Electronic supplementary material 2 (extended figure legend) to Svensson and Kvarnemo (2023). *How sexual and natural selection interact and shape the evolution of nests and nesting behaviour in fishes.* Phil. Trans. R. Soc. B. (10.1098/rstb.2022.0139)

Extended figure legend to figure 1.

a) The male white-spotted pufferfish *Torquigener albomaculosus* (Tetraodontidae) builds an elaborate construction of distinct radial valleys and rings up to 2 m in diameter. The male courts females and they spawn in the construction, which thereafter deteriorates, although some maintenance is carried out during paternal care [1, 2] (photo credit: Hiroshi Kawase, Coastal Branch of Natural History Museum and Institute, Chiba, Japan).

b) A male redtail chub, *Nocomis effuscus* (Leuciscidae), building on his dome nest made of rocks. Other species of minnows (Leuciscidae) often join the nest builders and spawn at such nests. Because they dilute the predation risk of both eggs and nest builders, they are considered mutualistic nest associates. Species of mutualistically spawning nest associates in the figure include, from the upper left: striped shiner, *Luxilus chrysocephalus*, Tennessee shiner, *Notropis leuciodus,* and rosyside dace, *Clinostomus funduloides* [3]. All these species belong to the Leuciscidae family. For species identification, see figure S1 (credit for photo and species identification: Isaak Szabo).

c) A male sand goby, *Pomatoschistus minutus* (Gobiidae), in the entrance of his nest in an aquarium experiment. In nature this species uses e.g. bivalve shells or rocks as nest sites, but in the lab, a halved flowerpot is used. The nest is built by the male by using his caudal fin to cover the pot with sand. He uses his mouth and fins to dig out a burrow underneath the pot and to form a small entrance. Finally, he prepares the inside of the pot with a sperm-containing mucus, produced by the sperm duct glands [4, 5]. Marks from the shovelling of sand on top of the nests are visible as a faint radial pattern around the nest (photo credit: Ola Svensson).

d) An excerpt of a painting from 1879 by A. F. Lydon (1836-1917) showing a nest of the three-spined stickleback, *Gasterosteus aculeatus* (Gasterosteidae). The male nest builder in red nuptial coloration is shown above the nest and the spawning female is inside it. The male builds the nest of algae and other plant parts, held together by a glucoprotein-based glue, produced in the kidneys [6] (credit: Public domain).

e) A male *Lamprologus callipterus* (Cichlidae) builds a nest by collecting many empty *Neuthauma* shells. The mottled brown females, which are much smaller than males, use the shells as breeding sites. Each female guards her eggs and shell, while the male (being too large to enter any of the shells) guards the nest [7]. The fish directly under the male is probably a dwarf male, that is, a parasitically spawning alternative reproductive tactic [8]. Several individuals of another species of cichlid, *Telmatochromis vittatus* (Cichlidae) are visible. This species collects no shells of its own but uses *L. callipterus* nests as breeding sites [9]. There are potentially two other species of cichlids in the photo. For species identification, see figure S1 (credit for photo and species identification: Ad Konings).

f) The catfish *Hoplosternum littorale* (Callichthyidae) male builds a bubble nest from mucus covered bubbles produced in the buccal cavity. He uses his modified pectoral fins to direct the bubbles to the pelvic fins where they are whipped into a foam. The pectoral fins are also used to insert plant parts into the nest [10] (photo credit: Joel Rahkonen).

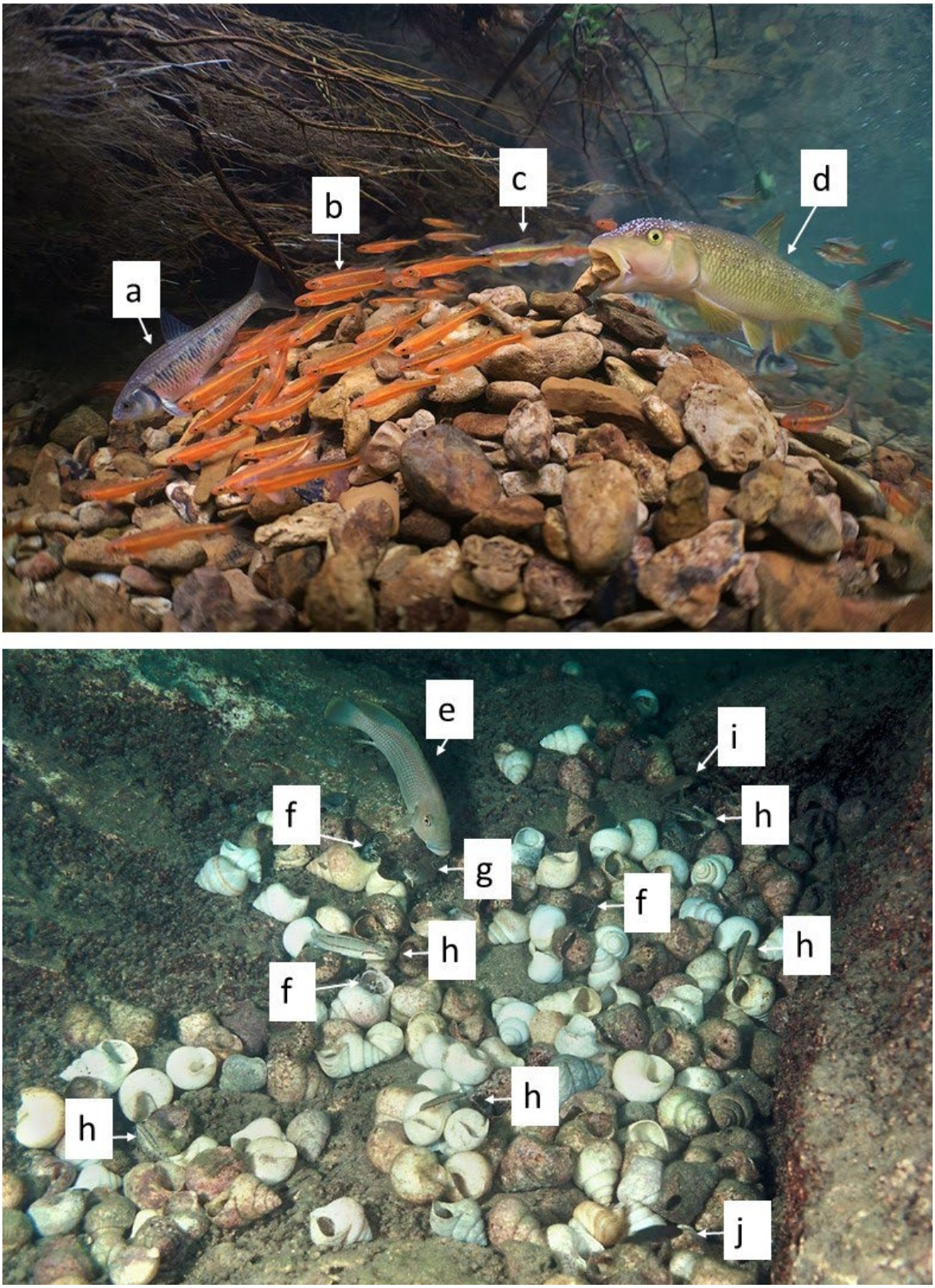

Figure S1. Species identification to figure 1c and figure 1e. Upper picture from a stream in central Tennessee, USA: (a) striped shiner, *Luxilus chrysocephalus*, (b) Tennessee shiner, *Notropis leuciodus,* (c) rosyside dace, *Clinostomus funduloides* and (d) redtail chub, *Nocomis effuscus* (credit for photo and species identification: Isaak Szabo). Lower picture from Mbita Island, Zambia: (e) male *Lamprologus callipterus*, (f) female *L. callipterus*, (g) probably a dwarf male of *L. callipterus*, (h) *Telmatochromis vittatus*, (i) probably a female of *Lamprologus calliurus* and (j) probably a juvenile of *Telmatochromis dhonti* (credit for photo and species identification: Ad Konings).

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