Supplementary information for:

One size does not fit all: variation in anatomical traits associated with emersion behavior in mudskippers (Gobiidae: Oxudercinae)

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Supplementary table 1. Summary of emergence behavior of Oxudercinae gobies. Modified from Zhang (2001)

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Supplementary figure 1. Distributions of Pagel’s λ and Blomberg’s K simulations

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| Supplementary Table 1. Summary of emergence behavior of Oxudercinae gobies. Modified from Zhang (2001) | | | | |
|  |  |  |  |  |
| Group | Species | Emersion Behavior | | Character |
| High Tide | Low tide |
| 1 | *A. punctatus* | In water, presumably swimming as ordinary pelagic fishes | In water, rarely exposing their bodies | Aquatic |
| 3 | *O. dentatus Pss. Elongatus* | In water, whether staying in the burrows or swimming remains unknown | In water, sometimes exposing their eyes to air; occasionally out of water, moving quickly between pools | Between 1 and 3 |
| 3 | *S. histophorus B. pectinirostris* | In water, staying in their burrows | Out of water, moving across mudflats but frequently returning to pools | Simi-terrestrial |
| 4 | *B. boddarti Pn. schlosseri* | In water, usually staying in their burrows, but sometimes out of water, waiting ebbs, on shores with vegetation | Out of water, wandering on mudflats (*B. boddarti* and sub-adult *Pn. schlosseri*), or staying in the burrows with head and dorsal body exposed to air (*Pn. schlosseri*) | Between 3 and 5 |
| 5 | *Ps. Argentilineatus Ps. Modestus* | Out of water, waiting on sand, stone, or stakes reaching out of water until the tide ebbs. | Out of water, contacting water pools, but seldom completely submerged | Terrestrial |

Supplementary table 2. Mean trait values from Zhang (2001).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species  non-tissue specific traits: EG DB P IEC MC CC | Tissue location | No. of scale layers | Tier of middle cells | Middle layer thickness (μm) | Capillary density (/mm) | Diffusion distance (μm) |
|  | H | 8 | 10‐20 | 63‐113 | 36 | 3 |
| *Periophthalmodon* | O | 5‐6 | 9‐10 | 125‐130 | 11 | 13 |
| *schlosseri* | D | 5 | 1‐3 | 63‐70 | 19 | 5 |
|  | A | 5 | 4‐8 | 125‐130 | 5\* | 146 |
| 4 X X + + + | C | 4‐5 | 2‐4 | 50‐75 | 8\* | 78 |
|  | H | 1 | 1‐4 | 23‐75 | 27 | 3 |
| *Periophthalmus* | O | 0 | 3‐4 | 75‐125 | 22 | 4 |
| *argentilineatus* | D | 2 | 1‐4 | 25‐50 | 27 | 2 |
|  | A | 2‐3 | 1‐4 | 20‐63 | 11 | 10 |
| 5 X X + X + | C | 3 | 1‐6 | 20‐60 | 6 | 17 |
|  | H | 1 | 3‐6 | 63‐100 | 36 | 2 |
| *Periophthalmus* | O | 0 | 3‐6 | 63‐100 | 29 | 2 |
| *modestus* | D | 1 | 3‐6 | 80‐120 | 32 | 2 |
|  | A | 1 | 1‐7 | 25‐50 | 9 | 4 |
| 5 X X + X + | C | 2‐3 | 1‐4 | 25‐70 | 16 | 5 |
|  | H | 2‐4 | 2‐4 | 30‐40 | 11\* | 13 |
| *Pseudapocryptes* | O | 1 | 3‐7 | 20‐90 | 8\* | 47 |
| *elongatus* | D | 2‐4 | 5‐7 | 75‐110 | 2\* | 117 |
|  | A | 1 | 3‐7 | 50‐150 | 5\* | 88 |
| 2 + X + + + | C | 2‐4 | 3‐7 | 25‐50 | 4\* | 89 |
|  | H | 0 | 2‐5 | 35‐50 | 16 | 2 |
| *Scartelaos* | O | 0 | 2‐5 | 14‐25 | 6 | 3 |
| *histophorus* | D | 0 | 1‐2 | 10‐27 | 10 | 6 |
|  | A | 0 | 1‐2 | 15‐25 | 8\* | 20 |
| 3 + + + + + | C | 1 | 1‐2 | 13‐35 | 6\* | 24 |
|  | H | 5‐8 | 12‐17 | 43‐108 | 26 | 2 |
| *Boleophthalmus* | O | 5‐8 | >10 | 50‐60 | 16 | 5 |
| *boddarti* | D | 3‐4 | 13 | 36‐76 | 16 | 3 |
|  | A | 3‐4 | 3‐5 | 20‐60 | 6\* | 28 |
| 4 + + + + X | C | 3‐4 | 3‐5 | 12‐20 | 8\* | 29 |
|  | H | 1 | 17‐18 | 290‐344 | 15 | 3 |
| *Boleophthalmus* | O | 0 | 13‐14 | 75‐138 | 11 | 3 |
| *pectinirostris* | D | 1 | 9‐15 | 75‐163 | 16 | 4 |
|  | A | 1 | 11 | 238‐313 | 4\* | 22 |
| 3 + + + + X | C | 2 | 8‐10 | 65‐75 | 8\* | 49 |
|  | H | 1 | 1‐2 | 0‐33 | 0 | NA |
| *Apocryptodon* | O | 0 | 4‐6 | 20‐125 | 0 | NA |
| *punctatus* | D | 1 | 1‐4 | 10‐36 | 0 | NA |
|  | A | 1 | 0‐2 | 5‐18 | 0 | NA |
| 1 X X X + + | C | 2‐3 | 1‐4 | 5‐40 | 0 | NA |
|  | H | 0 | 2‐5 | 15‐51 | 7\* | 28 |
| *Oxuderces* | O | 0 | 2‐5 | 51‐115 | 12\* | 86 |
| *dentatus* | D | 1 | 2‐5 | 26‐64 | 5\* | 59 |
|  | A | 1 | 2‐5 | 18‐51 | 8\* | 45 |
| 2 X X X + + | C | 2‐3 | 2‐5 | 20‐25 | 16\* | 56 |

Tissue locations include: top of the head (H), outer surface of operculum (O), dorso-lateral body near the first dorsal fin (D), posterior portion of the abdomen (A), and the lateral side of the caudal peduncle (C). Traits listed under species’ name are; emersion group (EG), dermal bulge (DB), papilla (P), Intra-epidermal capillary (skin) (IEC), mucous cells (MC), and Chloride cell (CC). X = absence and + = presence. “NA” represents missing data.

Supplementary table 3. Trait correlation. The β coefficient based on PGLS (binary traits are based on PGLMM) with each pairwise set of traits above the diagonal. For each model, the left column is the response variable and top row is the predicter variables. Parentheses contain two p-values (non-adjusted/adjusted via Bonferroni correction). Bold values showed [near] statistical significance after correction for multiple comparisons. Correlation coefficient (r) between traits below the diagonal with P values in parentheses. Each table is tissues specific as noted in the top left with the exception of the highlighted squares. Tissues include the head (H), outer surface of operculum (O), dorsolateral body near the first dorsal fin (D), posterior portion of the abdomen (A), and the lateral side of the caudal peduncle (C). The highlighted squares are non-tissues specific traits which are in the form of presence-absence data across the whole body (thus they are the same values repeated in each table).

See attached .xlsx file

Supplementary table 4. Phylogenetic Signal

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Tissue location | Emersion group | No. of scale layers | Tier of middle cells | Middle layer thickness (μm) | Capillary density (/mm) | Diffusion distance (μm) | Non-tissue specific measurements | |  |
|  | H | 1.0 | 0 | 0.999 | <.001 | 0.986 | <.001 | Dermal bulge | 1.0 | |
|  | O | 1.0 | 0 | 0.999 | 0.286 | 0.999 | <.001 | Papilla | 1.0 | |
| Pagel’s λ | D | 1.0 | 0 | 0.999 | <.001 | 0.999 | 0.999 | Intra-epidermal capillary | 1.0 | |
|  | A | 1.0 | 0 | <.001 | <.001 | 0.602 | 0.999 | Mucous cell | 1.0 | |
|  | C | 1.0 | 0 | <.001 | <.001 | <.001 | 0.999 | Chloride cell | 1.0 | |
|  |  |  |  |  |  |  |  |  |  | |
|  | H | NA | 0.626 | 0.890 | 0.564 | 1.420 | 1.194 |
| Blomberg’s *K* | O | NA | 0.538 | 0.842 | 0.784 | 1.115 | 1.023 |
| D | NA | 0.691 | 1.162 | 0.538 | 1.707 | 1.354 |
| A | NA | 0.712 | 0.566 | 0.514 | 0.970 | 0.799 |
|  | C | NA | 0.722 | 0.646 | 0.551 | 0.612 | 0.870 |

Phylogenetic signal calculated with Pagel’s λ and Blomberg’s *K*. Tissue locations include: top of the head (H), outer surface of operculum (O), dorsolateral body near the first dorsal fin (D), posterior portion of the abdomen (A), and the lateral side of the caudal peduncle (C). Traits in the final column are not tissue specific but instead presence/absence across the full specimen.

Supplementary figure 1. Distributions of Pagel’s λ (left plots) and Blomberg’s K (right plots) based on 1000 randomizations of trait data. Red solid lines indicate the upper 95% confidence interval. Black dashed lines represent observed values as reported in Table 2. An asterisk above plots represents observed values falling above the upper 95% confidence interval of simulations. Tissues include: H) top of the head, O) outer surface of operculum, D) dorso-lateral body near the first dorsal fin, A) posterior portion of the abdomen, and C) the lateral side of the caudal peduncle. Species level traits are at the specimen, not tissue level.











