**SI File 1: Supplementary Tables**

Mongiardino Koch N & Thompson JR – A Total-Evidence Dated Phylogeny of Echinoidea Combining Phylogenomic and Paleontological Data

**Table S1:** Genomic resources used to build the phylogenomic dataset and statistics of the bioinformatic pipeline used for assembly, curation and orthology inference. Data types are single-end transcriptomes (SE), pair-end transcriptomes (PE) and protein models derived from genomes (PM). Mean insert size is expressed in number of base pairs. Read pairs shows the number of read pairs in each dataset after processing with Trimmomatic. Those further removed by the curation steps taken by Agalma are shown as percentages, resulting in the final number of read pairs retained. These were then used for transcriptome assembly. The assemblies were further sanitized with alien\_index and CroCo, and the transcripts removed by both of these are shown as a percentage of the original transcriptome size (see also Fig. S1 of SI File 2). Number of loci shows the occupancy of terminals in the supermatrix generated by Agalma (2,356 loci at 70% occupancy), after which loci were further removed by TreeShrink resulting in the final occupancy (also shown in Fig S3 of SI File 2).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Accession number** | **Data type** | **Mean insert size** | **Read pairs** | **Removed by Agalma** | **Read pairs retained** | **Assembled transcripts** | **% protein coding** | **Removed by alien\_index** | **Removed by CroCo** | **# of loci** | **Removed by TreeShrink** | **Final occupancy** |
| *Abatus agassizii* | SRR1324764  SRR1324765 | SE | - | - | - | - | 166,219 | - | 0.63 | - | 852 | 9 | 35.8 |
| *Abatus cordatus* | SRR1324766  SRR1324767  SRR1324768  SRR1324769  SRR1324770  SRR1324771  SRR1324772  SRR1324773 | SE | - | - | - | - | 105,735 | - | 0.21 | - | 783 | 5 | 33.0 |
| *Apostichopus parvimensis* | SRR2484238 | PE | 244.58 | 161,967,254 | 12.74 | 141,326,465 | 290,709‬ | 43.3 | 2.06 | - | 1393 | 13 | 58.6 |
| *Araeosoma leptaleum* | SRR7513578 | PE | 238.2 | 32,824,194 | 22.12 | 25,565,104 | 134,493 | 45.2 | 0.15 | 0.79 | 2079 | 13 | 87.7 |
| *Arbacia lixula* | SRR2982357  SRR2982366 | PE | 170.9 | 39,825,874 | 24.26 | 30,163,261 | 112,338 | 40.7 | 1.00 | - | 2156 | 18 | 90.7 |
| *Asthenosoma varium* | SRR7513575 | PE | 191.8 | 67,577,575 | 14.01 | 58,110,236 | 168,247 | 43.9 | 0.12 | - | 2169 | 18 | 91.3 |
| *Brissus obesus* | SRR7513590 | PE | 237.1 | 30,348,945 | 25.65 | 22,564,575 | 98,540‬ | 22.4 | 0.07 | 0.79 | 1284 | 5 | 54.3 |
| *Caenopedina hawaiiensis* | SRR7513589 | PE | 259.2 | 38,105,472 | 27.93 | 27,462,085 | 74,577‬ | 43.1 | 0.14 | 1.33 | 1943 | 3 | 82.3 |
| *Clypeaster rosaceus* | SRR7513591 | PE | 198.6 | 66,754,370 | 12.34 | 58,518,636 | 175,905 | 30.7 | 0.06 | 0.18 | 2118 | 3 | 89.8 |
| *Clypeaster subdepressus* | SRR7513586 | PE | 203.0 | 84,561,739 | 11.93 | 74,475,117 | 193,121‬ | 37.4 | 0.17 | 4.70 | 2085 | 4 | 88.3 |
| *Colobocentrotus atratus* | SRR7513588 | PE | 299.5 | 42,546,671 | 24.95 | 31,932,067 | 84,234‬ | 39.9 | 0.10 | 0.76 | 2030 | 3 | 86.0 |
| *Conolampas sigsbei* | SRR7513579 | PE | 198.1 | 41,056,403 | 11.41 | 36,373,405 | 194,877 | 28.8 | 0.10 | - | 1741 | 4 | 73.7 |
| *Cystechinus giganteus* | SRR7513585 | PE | 274.9 | 34,233,585 | 26.58 | 25,134,883 | 121,913 | 24.8 | 0.11 | 0.29 | 1126 | 3 | 47.7 |
| *Dendraster excentricus* | SRR2844623 | PE | 197.6 | 28,537,534 | 11.01 | 25,396,389 | 149,098 | 12.8 | 0.06 | - | 621 | 7 | 26.1 |
| *Diadema setosum* | SRR7513577 | PE | 262.3 | 33,702,734 | 28.65 | 24,047,902 | 74,237 | 15.6 | 0.13 | 0.62 | 503 | 4 | 21.2 |
| *Echinarachnius parma* | SRR1139193 | PE | 212.5 | 40,256,046 | 13.10 | 34,984,323 | 137,615 | 38.2 | 0.09 | - | 2022 | 9 | 85.4 |
| *Echinocardium cordatum* | SRR1324911  SRR1324912  SRR1324913  SRR1324914  SRR1324915  SRR1324916  SRR1324917 | SE | - | - | - | - | 754,016 | - | 0.12 | - | 1774 | 6 | 75.0 |
| *Echinocardium mediterraneum* | SRR1324904  SRR1324905  SRR1324906  SRR1324907  SRR1324908  SRR1324909  SRR1324910 | SE | - | - | - | - | 348,230 | - | 0.11 | - | 2057 | 2 | 87.2 |
| *Echinocyamus crispus* | SRR7513576 | PE | 255.6 | 30,774,438 | 35.09 | 19,975,621 | 239,865‬ | 16.9 | 0.09 | 0.10 | 1209 | 12 | 50.8 |
| *Echinometra mathaei* | SRR7513581 | PE | 263.8 | 44,005,972 | 15.28 | 37,283,121 | 106,253 | 27.8 | 0.19 | 1.12 | 1779 | 0 | 75.5 |
| *Eucidaris tribuloides* | SRR1138704 | PE | 190.6 | 16,611,359 | 10.79 | 14,818,478 | 57,752 | 21.4 | 0.89 | - | 695 | 7 | 29.2 |
| *Evechinus chloroticus* | SRR1014619 | PE | 164.2 | 23,380,500 | 17.16 | 19,367,504 | 95,891‬ | 38.1 | 0.12 | - | 2097 | 0 | 89.0 |
| *Heliocidaris erythrogramma* | SRR1211283 | PE | 169.9 | 34,293,765 | 12.66 | 29,951,034 | 61,346‬ | 30.7 | 0.10 | - | 1638 | 0 | 69.5 |
| *Holothuria forskali* | SRR5109955 | PE | 171.2 | 80,911,707 | 12.88 | 70,490,724 | 126,770 | 34.5 | 0.13 | - | 1386 | 13 | 58.3 |
| *Leptosynapta clarki* | SRR1695478 | PE | 263.7 | 23,603,975 | 59.93 | 9,457,279 | 93,703‬ | 31.0 | 0.19 | - | 845 | 7 | 35.6 |
| *Lissodiadema lorioli* | SRR7513580 | PE | 315.1 | 36,578,442 | 22.26 | 28,436,004 | 80,963 | 33.0 | 0.17 | 0.39 | 1251 | 11 | 52.6 |
| *Loxechinus albus* | SRR7348687  SRR7348688  SRR7348691  SRR7348692 | PE | 349.0 | 19,261,189 | 42.33 | 11,108,353 | 107,694 | 39.3 | 0.22 | - | 2183 | 1 | 92.6 |
| *Lytechinus variegatus* | SRR1139214 | PE | 275.2 | 30,644,263 | 12.50 | 26,812,944 | 100,374‬ | 38.1 | 0.05 | - | 2164 | 8 | 91.5 |
| *Mellita tenuis* | SRR7513583 | PE | 279.8 | 34,088,387 | 53.69 | 15,785,903 | 118,767 | 27.9 | 0.10 | 0.28 | 1670 | 7 | 70.6 |
| *Meoma ventricosa* | SRR7513582 | PE | 184.1 | 46,897,779 | 10.18 | 42,125,813 | 90,165‬ | 34.3 | 0.11 | 0.22 | 1819 | 1 | 77.2 |
| *Mesocentrotus nudus* | SRR5017175 | PE | 256.8 | 28,823,832 | 9.08 | 26,207,098 | 103,317‬ | 45.7 | 1.95 | - | 2163 | 4 | 91.6 |
| *Paracentrotus lividus* | SRR1735501 | PE | 193.7 | 20,175,205 | 10.49 | 18,059,227 | 141,706‬ | 36.0 | 0.06 | - | 2190 | 2 | 92.9 |
| *Prionocidaris baculosa* | SRR7513584 | PE | 269.7 | 38,619,001 | 14.96 | 32,839,869 | 137,112‬ | 22.9 | 0.10 | 3.03 | 1317 | 13 | 55.3 |
| *Psammechinus miliaris* | SRR5396289 | PE | 172.0 | 38,443,261 | 33.58 | 25,534,190 | 157,399 | 25.6 | 0.12 | - | 2032 | 0 | 86.2 |
| *Sphaerechinus granularis* | SRR1139199 | PE | 181.8 | 41,722,413 | 15.14 | 35,404,566 | 127,628 | 33.3 | 0.06 | - | 2102 | 3 | 89.1 |
| *Stomopneustes variolaris* | SRR7513587 | PE | 257.3 | 34,056,015 | 28.10 | 24,486,356 | 132,538 | 23.6 | 0.05 | 0.28 | 1535 | 2 | 65.1 |
| *Strongylocentrotus purpuratus* | GCF 000002235.4 | PM | - | - | - | - | - | - | - | - | 2213 | 13 | 93.4 |

**Table 2:** Species sampled in the molecular, morphological, and stratigraphic datasets. Here and throughout, the nomenclature used follows that of the World Echinoidea Database (Kroh and Mooi 2019), where citations to authorities and dates for scientific names can be found. The names of terminals for the total-evidence dated analysis are those of the least inclusive clade containing the species sampled across all datasets.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Clade** | **Morphological data** | **Molecular data** | **Stratigraphic data** | **Terminal name (TED analysis)** |
| Abertellidae | *Abertella aberti* | - | *Abertella aberti* | *Abertella aberti* |
| Acrolusiidae | *Acrolusia gauthieri* | - | *Acrolusia gauthieri* | *Acrolusia gauthieri* |
| Acropeltidae | *Acropeltis aequituberculata* | - | *Acropeltis aequituberculata* | *Acropeltis aequituberculata* |
| Acrosaleniidae | *Acrosalenia spinosa* | - | *Acrosalenia spinosa* | *Acrosalenia spinosa* |
| Aeropsidae | *Aeropsis rostrata* | - | *-* | *Aeropsis rostrata* |
| Aeropsidae (Corasterinae) | *Coraster vilanovae* | - | *Coraster vilanovae* | *Coraster vilanovae* |
| Anorthopygidae | *Anorthopygus orbicularis* | - | *Anorthopygus orbicularis* | *Anorthopygus orbicularis* |
| Antillasteridae | *Antillaster cubensis* | - | *Antillaster lamberti* | *Antillaster* |
| Apatopygidae | *Apatopygus recens* | - | - | *Apatopygus recens* |
| Arbaciidae | *Arbacia lixula* | *Arbacia lixula* | - | *Arbacia lixula* |
| Arbaciidae | *Coelopleurus equis*  *Coelopleurus maillardi* | - | *Coelopleurus equis* | *Coelopleurus* |
| Archiaciidae | *Archiacia sandalina* | - | *Archiacia sandalina* | *Archiacia sandalina* |
| Aspidodiadematidae | *Aspidodiadema jacobyi* | - | *-* | *Aspidodiadema jacobyi* |
| Asterostomatidae | *Asterostoma pawsoni* | - | *Asterostoma pawsoni* | *Asterostoma pawsoni* |
| Astriclypeidae | *Astriclypeus mannii* | - | *Astriclypeus mannii* | *Astriclypeus mannii* |
| Brissidae | *Brissus unicolor* | *Meoma ventricosa* | - | Brissidae |
| Brissidae (Brissopsinae) | *Brissopsis lyrifera*  *Brissopsis alta* | - | - | *Brissopsis* |
| Calymnidae | *Calymne relicta* | - | - | *Calymne relicta* |
| Cardiasteridae | *Cardiaster granulosus* | - | *Cardiaster granulosus* | *Cardiaster granulosus* |
| Cardiasteridae (Cardiotaxinae) | *Sternotaxis plana* | - | *Sternotaxis plana* | *Sternotaxis plana* |
| Carnarechinidae | *Carnarechinus clypeatus* | - | - | *Carnarechinus clypeatus* |
| Cassidulidae | *Cassidulus caribaearum* | - | - | *Cassidulus caribaearum* |
| Cidaridae (Cidarinae) | *Cidaris cidaris* | *Eucidaris tribuloides* | - | Cidarinae |
| Cidaridae (Goniocidarinae) | *Goniocidaris tubaria* | - | *Goniocidaris tubaria* | *Goniocidaris tubaria* |
| Cidaridae (Phyllacanthina) | *Phyllacanthus imperialis*a | - | *-* | *Phyllacanthus* |
| Cidaridae (Stereocidarinae) | *Stereocidaris sceptrifera* | *-* | - | *Stereocidaris* |
| Cidaridae (Stylocidarinae) | *Stylocidaris* *affinis*a | *Prionocidaris baculosa* | - | Stylocidarinae |
| Cidaridae (Typocidarinae) | *Typocidaris malum* | - | *Typocidaris malum* | *Typocidaris malum* |
| Claviasteridae | *Claviaster libycus* | - | *Claviaster libycus* | *Claviaster libycus* |
| Clypeasteridae | *Clypeaster rosaceus* | *Clypeaster rosaceus* | *-* | *Clypeaster rosaceus* |
| Clypeasteridae (Ammotrophinae) | *Ammotrophus cyclius* | - | *-* | *Ammotrophus cyclius* |
| Clypeasteridae (Arachnoidinae) | *Arachnoides placenta*  *Fellaster zealandiae* | - | *Fellaster zelandiae* | Arachnoidinae |
| Clypeidae | *Clypeus plotii* | - | *Clypeus plotii* | *Clypeus plotii* |
| Clypeolampadidae | *Clypeolampas ovatus* | - | *Clypeolampas ovatus* | *Clypeolampas ovatus* |
| Coenholectypidae | *Coenholectypus macropygus* | - | *Coenholectypus macropygus* | *Coenholectypus macropygus* |
| Collyritidae | *Collyrites ellipticus* | - | *Collyrites ellipticus* | *Collyrites ellipticus* |
| Conoclypidae | *Conoclypus conoideus* | - | *Conoclypus conoideus* | *Conoclypus conoideus* |
| Conulidae | *Conulus albogalerus* | - | *Conulus albogalerus* | *Conulus albogalerus* |
| Corystusidae | *Corystus dysasteroides*  *Corystus relictus* | - | *Corystus disasteroides* | *Corystus* |
| Ctenocidaridae | *Ctenocidaris speciosa* | - | - | *Ctenocidaris speciosa* |
| Dendrasteridae | *Dendraster excentricus* | *Dendraster excentricus* | - | *Dendraster excentricus* |
| Desorellidae | *Desorella elata* | *-* | *Desorella elata* | *Desorella elata* |
| Diadematidae | *Diadema antillarum* | *Lissodiadema lorioli* | *-* | Diadematidae |
| Diplocidaridae | *Diplocidaris gigantea* | - | *Diplocidaris gigantea* | *Diplocidaris gigantea* |
| Diplopodiidae | *Diplopodia pentagona* | - | *Diplopodia pentagona* | *Diplopodia pentagona* |
| Disasteridae | *Disaster granulosus* | - | *Disaster granulosus* | *Disaster granulosus* |
| Discoididae | *Discoides subuculus* | - | *Discoides subuculus* | *Discoides subuculus* |
| Echinarachniidae | *Echinarachnius parma* | *Echinarachnius parma* | *-* | *Echinarachnius parma* |
| Echinidae | *Echinus esculentus* | - | *-* | *Echinus esculentus* |
| Echinocorythidae | *Echinocorys scutata* | - | *Echinocorys scutata* | *Echinocorys scutata* |
| Echinolampadidae | *Echinolampas ovata* | *Conolampas sigsbei* | - | Echinolampadidae |
| Echinometridae | *Echinometra lucunter* | *Evechinus chloroticus* | - | Echinometridae |
| Echinoneidae | *Echinoneus cyclostomus* | *-* | *Echinoneus cyclostomus* | *Echinoneus cyclostomus* |
| Echinothuriidae (Echinothuriinae) | *Araeosoma fenestratum* | *Araeosoma leptaleum* | - | *Araeosoma* |
| Echinothuriidae (Hygrosomatinae) | *Hygrosoma petersii* | - | - | *Hygrosoma petersii* |
| Echinothuriidae (Sperosomatinae) | *Sperosoma grimaldii* | - | - | *Sperosoma grimaldii* |
| Emiratiidae | *Emiratia raskhaimahensis* | - | *Emiratia raskhaimahensis* | *Emiratia raskhaimahensis* |
| Eoscutellidae | *Eoscutella coosensis* | - | *Eoscutella coosensis* | *Eoscutella coosensis* |
| Eupatangidae | *Eupatagus valenciennesi*  *Eupatagus lymani* | - | *-* | *Eupatagus* |
| Eurypatagidae | *Eurypatagus ovalis* | - | *-* | *Eurypatagus ovalis* |
| Faujasiidae | *Faujasia apicalis*  *Faujasia eccentripora* | - | *Faujasia apicalis* | *Faujasia* |
| Faujasiidae (Stigmatopyginae) | *Stigmatopygus pulchellus* | - | *Stigmatopygus pulchellus* | *Stigmatopygus pulchellus* |
| Fibulariidae | *Echinocyamus pusillus* | *Echinocyamus crispus* | - | *Echinocyamus* |
| Fibulariidae | *Fibularia ovulum* | - | *-* | *Fibularia ovulum* |
| Fossulasteridae | *Fossulaster halli* | - | *Fossulaster halli* | *Fossulaster halli* |
| Galeritidae | *Galerites vulgaris* | - | *Galerites vulgaris* | *Galerites vulgaris* |
| Galeropygidae | *Galeropygus sublaevis* | - | *Galeropygus sublaevis* | *Galeropygus sublaevis* |
| Glyphocyphidae | *Glyphocyphus radiatus* | - | *Glyphocyphus radiatus* | *Glyphocyphus radiatus* |
| Glypticidae | *Glypticus heiroglyphicus* | - | *Glypticus hieroglyphicus* | *Glypticus hieroglyphicus* |
| Glyptocidaridae | *Glyptocidaris crenularis* | - | *Glyptocidaris crenularis* | *Glyptocidaris crenularis* |
| Goniophoridae | *Goniophorus lunulatus* | - | *Goniophorus lunulatus* | *Goniophorus lunulatus* |
| Hemiasteridae | *Hemiaster bufo* | - | *Hemiaster bufo* | *Hemiaster bufo* |
| Hemicidaridae | *Hemicidaris intermedia* | - | *Hemicidaris intermedia* | *Hemicidaris intermedia* |
| Hemipneustidae | *Hemipneustes striatoradiatus* | - | *Hemipneustes striatoradiatus* | *Hemipneustes striatoradiatus* |
| Heterodiadematidae | *Heterodiadema lybica* | - | *Heterodiadema lybica* | *Heterodiadema lybica* |
| Histocidaridae | *Histocidaris elegans* | - | - | *Histocidaris elegans* |
| Histocidaridae | *Histocidaris purpurata* | - | - | *Histocidaris purpurata* |
| Holasteridae | *Holaster nodulosus* | - | *Holaster nodulosus* | *Holaster nodulosus* |
| Holectypidae | *Holectypus depressus* | - | *Holectypus depressus* | *Holectypus depressus* |
| Hyboclypids | *Hyboclypus gibberulus*  *Hyboclypus sandalinus* | - | *Hyboclypus gibberulus* | *Hyboclypus* |
| Hyposaleniidae | *Hyposalenia stellulata* | - | *Hyposalenia stellulata* | *Hyposalenia stellulata* |
| Kamptosomatidae | *Kamptosoma asterias* | - | - | *Kamptosoma asterias* |
| Laganidae | *Laganum laganum* | - | - | *Laganum laganum* |
| Laganidae (Neolaganinae) | *Neolaganum durhami*  *Neolaganum archerensis* | - | *Neolaganum durhami* | *Neolaganum* |
| Loveniidae | *Breynia australasiae* | - | - | *Breynia australasiae* |
| Loveniidae | *Lovenia elongata* | - | - | *Lovenia elongata* |
| Loveniidae (Echinocardiinae) | *Echinocardium cordatum* | *Echinocardium mediterraneum* | - | *Echinocardium* |
| Macropneustidae | *Macropneustes deshayesi*  *Macropneustes mortoni* | - | *Macropneustes mortoni* | *Macropneustes* |
| Maretiidae | *Maretia planulata* | - | *Maretia planulata* | *Maretia planulata* |
| Megapneustidae | *Megapneustes grandis* | - | *Megapneustes grandis* | *Megapneustes grandis* |
| Mellitidae | *Mellita quinquiesperforata* | *Mellita tenuis* | *-* | *Mellita* |
| Micrasteridae | *Micraster coranguinum* | - | *Micraster coranguinum* | *Micraster coranguinum* |
| Micrasteridae (Cyclasterinae) | *Cyclaster regalis* | - | *-* | *Cyclaster regalis* |
| Micropygidae | *Micropyga tuberculata* | - | *-* | *Micropyga tuberculata* |
| Miocidaridae | *Eotiaris verneuiliana* | - | *Eotiaris verneuiliana* | *Eotiaris verneuiliana* |
| Monophorasteridae | *Monophoraster darwini* | - | *Monophoraster darwini* | *Monophoraster darwini* |
| Neoglobatoridae | *Adelopneustes montainvillensis* | - | *Adelopneustes montainvillensis* | *Adelopneustes montainvillensis* |
| Neolampadidae | *Neolampas rostellata* | - | *-* | *Neolampas rostellata* |
| Nucleolitidae | *Nucleolites scutatus* | - | *Nucleolites scutatus* | *Nucleolites scutatus* |
| Oligopygidae | *Haimea rutteni* | - | *Haimea rutteni* | *Haimea rutteni* |
| Oligopygidae | *Oligopygus wetherbyi*  *Oligopygus haldemai* | - | *Oligopygus haldemani* | *Oligopygus* |
| Orthopsidae | *Orthopsis miliaris* | - | *Orthopsis miliaris* | *Orthopsis miliaris* |
| Ovulasteridae | *Ovulaster gauthieri*  *Ovulaster protodecimae* | - | *Ovulaster protodecimae* | *Ovulaster* |
| Palaeostomatidae | *Palaeostoma mirabile* | - | - | *Palaeostoma mirabile* |
| Palaeotropidae | *Palaeotropus josephinae* | - | - | *Palaeotropus josephinae* |
| Paleopneustidae | *Paleopneustes cristatus* | - | - | *Paleopneustes cristatus* |
| Parasaleniidae | *Parasalenia gratiosa* | - | - | *Parasalenia gratiosa* |
| Parechinidae | *Parechinus angulosus* | *Paracentrotus lividus* | - | Parechinidae |
| Pedinidae | *Caenopedina cubensis* | *Caenopedina hawaiiensis* | - | *Caenopedina* |
| Pelanechinidae | *Pelanodiadema oolithicum*  *Pelanechinus corallina* | - | *Pelanechinus corallina* | Pelanechinidae |
| Periasteridae | *Periaster elatus* | - | *Periaster elatus* | *Periaster elatus* |
| Pericosmidae | *Pericosmus latus*  *Pericosmus cordatus* | - | *Pericosmus latus* | *Pericosmus* |
| Phormosomatidae | *Phormosoma placenta* | - | - | *Phormosoma placenta* |
| Phormosomatidae (Paraphormosomatinae) | *Paraphormosoma alternans* | - | - | *Paraphormosoma alternans* |
| Phymosomatidae | *Gauthieria radiata* | - | *Gauthieria radiata* | *Gauthieria radiata* |
| Phymosomatidae | *Phymosoma koenigi* | - | *Phymosoma koenigi* | *Phymosoma koenigi* |
| Plesiasteridae | *Plesiaster peini* | - | *Plesiaster peini* | *Plesiaster peini* |
| Plesiolampadidae | *Plesiolampas placenta* | - | *Plesiolampas placenta* | *Plesiolampas placenta* |
| Plexechinidae | *Plexechinus cinctus*  *Antrechinus nordenskjoldi* | - | *-* | Plexechinidae |
| Pliolampadidae | *Pliolampas vassalli* | - | *Pliolampas vassalli* | *Pliolampas vassalli* |
| Polycidaridae | *Polycidaris legayi*  *Polycidaris spinosa* | - | *Polycidaris suevica* | *Polycidaris* |
| Polydiaematidae | *Polydiadema mamillanum* | - | *Polydiadema mamillanum* | *Polydiadema mamillanum* |
| Pourtalesiidae | *Pourtalesia jeffreysi* | - | *-* | *Pourtalesia jeffreysi* |
| Prenasteridae | *Prenaster alpinus* | - | *Prenaster alpinus* | *Prenaster alpinus* |
| Protoscutellidae | *Protoscutella plana* | - | *Protoscutella plana* | *Protoscutella plana* |
| Pseudholasteridae | *Pseudholaster bicarinatus* | - | *Pseudholaster bicarinatus* | *Pseudholaster* |
| Pseudodiadematidae | *Pseudodiadema pseudodiadema* | - | *Pseudodiadema pseudodiadema* | *Pseudodiadema pseudodiadema* |
| Pseudosaleniidae | *Pseudosalenia aspera* | - | *Pseudosalenia aspera* | *Pseudosalenia aspera* |
| Psychocidaridae | *Roseicidaris morieri* | - | *Roseicidaris morieri* | *Roseicidaris morieri* |
| Psychocidaridae | *Tylocidaris ohshimai* | - | *-* | *Tylocidaris ohshimai* |
| Pygasteridae | *Pygaster semisulcatus* | - | *Pygaster semisulcatus* | *Pygaster semisulcatus* |
| Pygaulidae | *Pygaulus desmoulinsii* | - | *Pygaulus desmoulinsii* | *Pygaulus desmoulinsii* |
| Pygorhytidae | *Pygorhytis ringens* | - | *Pygorhytis ringens* | *Pygorhytis ringens* |
| Rhabdocidaridae | *Rhabdocidaris orbignyana* | - | *Rhabdocidaris orbignyana* | *Rhabdocidaris orbignyana* |
| Rotulidae | *Rotula deciesdigitatus* | - | *-* | *Rotula deciesdigitatus* |
| Saleniidae | *Salenia petalifera* | - | *Salenia petalifera* | *Salenia petalifera* |
| Saleniidae (Holosaleniini) | *Holosalenia batnensis* | - | *Holosalenia batnensis* | *Holosalenia batnensis* |
| Saleniidae (Salenocidarini) | *Salenocidaris varispina* | - | - | *Salenocidaris varispina* |
| Schizasteridaeb | *Brisaster fragilis* | - | - | *Brisaster fragilis* |
| Schizasteridaeb | *Ova canalifera* | *Abatus agassizii* | - | Schizasteridae |
| Scutasteridae | *Scutaster andersoni* | - | *Scutaster andersoni* | *Scutaster andersoni* |
| Scutellidae | *Scutella subrotunda* | - | *Scutella subrotunda* | *Scutella subrotunda* |
| Scutellinidae | *Scutellina lenticularis* | - | *Scutellina lenticularis* | *Scutellina lenticularis* |
| Scutellinoididae | *Scutellinoides patella* | - | *Scutellinoides patella* | *Scutellinoides patella* |
| Serpianotiaridae | *Serpianotiaris coaeva* | - | *Serpianotiaris coaeva* | *Serpianotiaris coaeva* |
| Somaliasteridae | *Somaliaster magniventer* | - | *Somaliaster magniventer* | *Somaliaster magniventer* |
| Spatangidae | *Spatangus purpureus* | - | *Spatangus purpureus* | *Spatangus purpureus* |
| Stegasteridae | *Stegaster gillieroni* | - | *Stegaster gillieroni* | *Stegaster gillieroni* |
| Stenonasteridae | *Stenonaster tuberculata* | - | *Stenonaster tuberculata* | *Stenonaster tuberculata* |
| Stomechinidae | *Stomechinus bigranularis* | - | *Stomechinus bigranularis* | *Stomechinus bigranularis* |
| Stomopneustidae | *Stomopneustes variolaris* | *Stomopneustes variolaris* | - | *Stomopneustes variolaris* |
| Strongylocentrotidae | *Strongylocentrotus droebachiensis* | *Strongylocentrotus purpuratus* | - | *Strongylocentrotus* |
| Taiwanasteridae | *Sinaechinocyamus mai* | - | - | *Sinaechinocyamus mai* |
| Temnopleuridae | *Temnopleurus toreumaticus* | - | - | *Temnopleurus toreumaticus* |
| Tithoniidae | *Tithonia convexa* | - | *Tithonia convexa* | *Tithonia convexa* |
| Toxasteridae | *Toxaster retusus* | - | *Toxaster retusus* | *Toxaster retusus* |
| Toxopneustidae | *Toxopneustes pileolus* | *Lytechinus variegatus* | - | Toxopneustidae |
| Triadotiaridae | *Triadotiaris grandaevus* | - | *Triadotiaris grandaevus* | *Triadotiaris grandaevus* |
| Trigonocidaridae | *Trigonocidaris albida* | - | - | *Trigonocidaris albida* |
| Unifasciidae | *Unifascia carolinensis* | - | *Unifascia carolinensis* | *Unifascia carolinensis* |
| Urechinidae | *Urechinus naresianus* | *Cystechinus giganteus*c | - | Urechinidae |
| Zeuglopleuridae | *Zeuglopleurus costulatus* | - | *Zeuglopleurus costulatus* | *Zeuglopleurus costulatus* |
| Echinoidea incertae sedis | *Glyptodiadema granulatum* | - | *Glyptodiadema granulatum* | *Glyptodiadema granulatum* |
| Stem Echinoidea (Archaeocidaridae) | *Archaeocidaris whatleyensis*  *Archaeocidaris. brownwoodensis* | - | *Archaeocidaris whatleyensis* | *Archaeocidaris* |
| Holothuroidea (Synallactida) | - | *Apostichopus parvimensis* | - | ***-*** |
| Holothuroidea (Holothuriida) | - | *Holothuria forskali* | - | ***-*** |
| Holothuroidea (Apodida) | - | *Leptosynapta clarki* | - | ***-*** |

a A. Kroh, personal communication.

b Given lack of knowledge of relationships within schizasterid spatangoids, the molecular data for *Abatus* could have been merged with the morphological data of either of the two representatives of the family. This decision however cannot have any effect on topology, and merging was thus performed at random.

c This species was identified as *Pilematechinus* sp. in Mongiardino Koch et al. (2018) but has since been identified as *Cystechinus* c.f. *giganteus* by R. Mooi.

**Table S3:** Inferred dates of divergence of major clades in our total-evidence dated analysis. Only clades ranked at or above the level of order are shown. Clades are defined based on the topologies of Figure 7 and Figure S12 (SI File 2), as well as the taxonomic changes proposed in the main text. If a clade is missing from the majority-rule consensus, the age of the mcc tree is shown. Age is expressed in Ma and includes the 95% highest posterior density. These dates should be taken with caution as many are constrained exclusively based on a morphological clock. For comparison, we have included the results of three other time-calibration studies. If those authors used multiple calibration approaches, their preferred method is reported. PL logarithmic = penalized likelihood method with logarithmic-penalty function. Clades with an asterisk were constrained for node dating. IGP = Informative gamma priors.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Clade** | **Age (this analysis)** | **Smith et al. (2006)**  **PL logarithmic** | **Nowak et al. (2013)**  **IGP** | **Thompson et al. (2017)** |
| Echinozoa\* | 465.6 (464.0-472.0) | - | - | 467.0 (464.0-470.0) |
| All sampled Echinoidea\* | 352.0 (346.7-367.7) | - | - |  |
| Crown group Echinoidea | 266.9 (245.1-287.3) | - | 276.2 (260.4-307.5) | 295.3 (265.0-341.9) |
| Cidaroidea/Cidaroida | 237.4 (212.6-263.8) | - | - |  |
| Crown group Cidaroida | 200.0 (184.0-220.1) | - | - |  |
| Euechinoidea | 257.8 (237.9-283.3) | 225 (197-253) | 222.0 (199.6-254.9) | 239.3 (220.0-252.8) |
| Aulodonta | 236.3 (210.9-267.0) | - | - | 230.7 (211.6-248.9) |
| Crown group Aulodonta | 219.9 (187.0-246.5) | - | 182.4 (123.6-237.9) |  |
| Carinacea | 248.3 (225.5-262.0) | 197 (165-229) | 202.5 (177.3-234.2) | 216.0 (194.2-235.0) |
| Echinacea + Calycina + (*Hemicidaris* + *Pseudodiadema*) | 233.8 (214.8-251.5) | - | - |  |
| Echinacea\* | 199.0 (182.7-218.0) | 182 (150-214) | 179.5 (133.5-219.9) | 195.6 (186.3-201.4) |
| Camarodonta + Stomopneustoida | 187.5 (175.0-204.9) | - | - |  |
| Camarodonta | 128.5 (106.5-154.3) | 125 (97-153) | 145.7 (102.7-186.9) | 148.8 (101.5-194.2) |
| Stomopneustoida | 174.7 (168.4-185.5) | - | - |  |
| Crown group Stomopneustoida | 59.2 (41.6-99.3) | - | - |  |
| Arbacioida | 185.4 (164.7-206.9) | - | - |  |
| Calycina | 212.4 (191.4-233.3) | - | - |  |
| Phymosomatoida | 191.5 (175.3-212.4) | - | - |  |
| Salenioida | 192.3 (172.2-214.6) | - | - |  |
| Irregularia | 238.2 (220.5-254.2) | - | - |  |
| Holectypoida | 213.1 (188.3-236.1) | - | - |  |
| Crown group Irregularia\* | 227.9 (210.4-242.5) | 190 (161-219) | 181.7 (171.6-198.4) | 172.2 (75.7-229.8) |
| Nucleolitoida + (Echinoneoida + Neognathostomata) | 223.2 (206.5-238.2) | - | - |  |
| Nucleolitoida | 215.4 (199.8-232.9) | - | - |  |
| Echinoneoida + Neognathostomata | 208.7 (183.5-229.2) | - | - | 128.3 (58.8-218.2) |
| Echinoneoida | 131.3 (99.0-166.0) | - | - |  |
| Neognathostomata | 167.1 (145.0-190.7) | 151 (118-184) | 113.7 (99.6-137.8) | 87.8 (46.0-196.5) |
| Clypeasteroida | 91.4 (58.0-128.5) | - | - |  |
| Crown group Clypeasteroida | 61.6 (28.4-96-9) | - | - |  |
| Cassiduloida + Oligopygoida + Scutelloida | 155.1 (128.3-168.9) | 114 (83-145) | 81.4 (54.4-107.2) | 63.3 (37.2-131.9) |
| Cassiduloida | 123.5 (102.5-146.6) | - | - |  |
| Oligopygoida | 85.6 (55.3-117.9) | - | - |  |
| Scutelloida\* | 111.2 (86.9-139.3) | - | - |  |
| Crown group Scutelloida | 87.3 (68.7-139.3) | 97 (68-126) | 61.3 (40.6-81.5) | 45.8 (30.9-81.3) |
| Atelostomata | 213.8 (195.3-231.8) | - | - |  |
| Crown group Atelostomata\* | 169.8 (153.6-200.0) | 174 (142-206) | 159.8 (150.8-174.0) | 122.8 (35.6-222.3) |
| Holasteroida | 143.4 | - | - |  |
| Crown group Holasteroida | 129.8 |  | - |  |
| Spatangoida | 165.5 | - | - |  |
| Crown group Spatangoida | 163.2 |  |  |  |