Endemism and conservation of the native freshwater fish fauna of Sulawesi, Indonesia

Lynne R. Parenti

Division of Fishes, PO Box 37012, MRC 159, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20013-7012, USA
e-mail: parentil@si.edu

Abstract

Sulawesi has an estimated 56 endemic freshwater fish species, 44 of which are atherinomorphs and the remainder of which are perciform gobioids and a species of terapontid. 25 of the 56 species have been described since 1989, and ten of these in the past decade. Most of these new species have been described from the central tectonic lake systems, but discoveries have also been made outside of this region. Continued exploration throughout Sulawesi is needed to confirm the natural distribution of known species and identify and describe new species. Voucher materials of all species should be archived in museum collections. Species flocks of the atherinomorph ricefishes and sailfin silversides, and other segments of the endemic biota, are potential models for *in situ* studies of evolution and ecology. All endemics are under threat and many species have likely already gone extinct. Endemic species are ideal icons to draw attention to the endemic freshwater fish fauna of Sulawesi and encourage its conservation and its pivotal role in understanding the history of the biota of the Indo-Australian Archipelago.

Key words: endemism, conservation, freshwater fish, Indonesia, Sulawesi.

Introduction

Sulawesi (Figure 1), Indonesia, the eleventh largest island in the world, has long been celebrated for its high number of endemic species in an array of taxa, including fishes, molluscs, and mammals (Musser, 1982, Whitten, Mustafa & Henderson, 1987; Kottelat *et al.*, 1993; Haase & Bouchet, 2006). Extreme morphological specializations, such as gigantism or dwarfism, also distinguish the native biota of Sulawesi and bolster its unique role in our understanding of biological evolution: "For a biologist, there is no island like Sulawesi for unusual animals" (Iskandar & Nio, 1996:39).

Endemism is a key concept in systematics and biogeography: a species is endemic to an area or region if it lives there and nowhere else[1]. Endemism is also a key concept in conservation biology: areas where endemism and species diversity are high are often ranked highest in conservation priority and identified as conservation 'hotspots,' following Myers (1988). The central tectonic lakes region of Sulawesi was identified as such a 'hotspot' by Kottelat & Whitten (1996: fig. 2) based on the high endemism and threatened status of its native freshwater fish fauna. This was reflected in the preliminary classification of Sulawesi in three numbered ecoregions by Abell *et al.* (2008): Sulawesi, as one large region, including Malili Lakes and Lake Poso, as two smaller regions (Figure 1).

Sulawesi lies geographically in the heart of Wallacea, named after legendary British naturalist Alfred Russel Wallace (1823-1913) who explored the Malay Archipelago in the mid 19th century (Wallace, 1869). Wallace's famous observation that the biota of the western portion of the Malay Archipelago was Asian, distinct from that of the eastern portion which was Australian, was pivotal in his formulation of a theory of evolution that hinged on the interactions between organisms and their environment over time. Wallace's Line, one of many imaginary boundaries between segments of the biota, separates Borneo, in the west, from Sulawesi, in the east; division between the two biotas is not so abrupt or fixed that it can be marked by a single line (see Simpson, 1977). The two biotas overlap in the middle—Wallacea-- noted for its mixture of

[1] Being endemic is different from being native. Species native to an area, but not endemic, live in the area and also live elsewhere (see Parenti & Ebach, 2009).

western and eastern Indo-Australian Archipelago biotic segments, and its endemism (see Parenti & Ebach, 2010, and below).

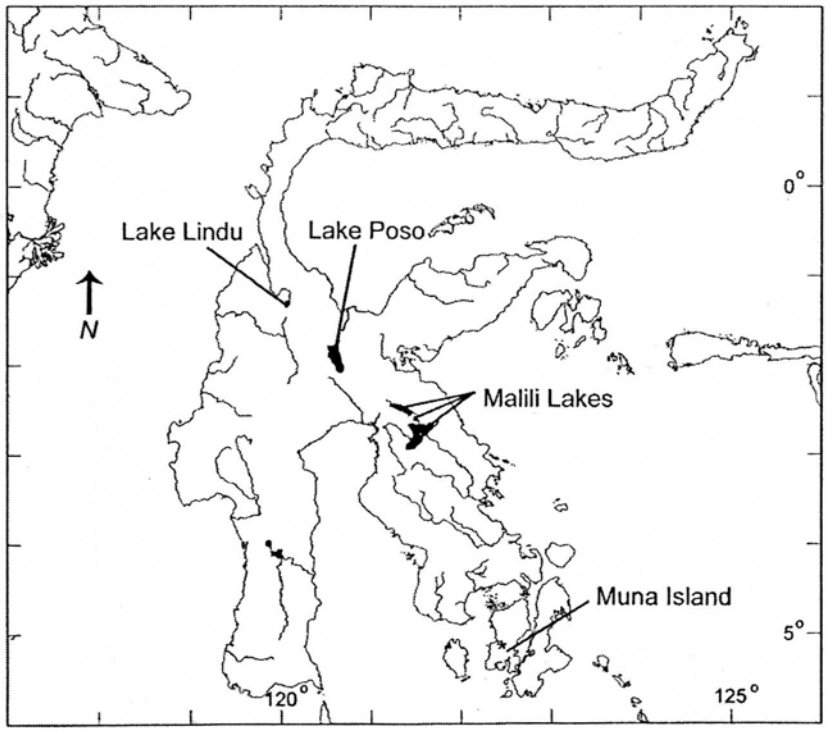

Figure 1. Outline map of the main island of Sulawesi and some associated smaller islands. Central tectonic lakes are labeled. Star (*) on Muna Island is approximate type locality of *Oryzias woworae* Parenti & Hadiaty (2010)

Wallace's visits to the island were limited largely to northern Sulawesi in and around Manado and southwestern Sulawesi in and around Makassar. It fell to two Swiss biologist and anthropologist cousins, Paul (1856 -1929) and Fritz (1859-1942) Sarasin, to explore the central Sulawesi tectonic region and bring the endemic lacustrine fauna to the attention of the scientific community (see Boulenger, 1897). The cousins Sarasin made two extensive expeditions to Sulawesi in 1893-1896 and 1902-1903 (Sarasin & Sarasin, 1897, 1898, 1905). They are remembered in the name of many Sulawesi endemics, together, as in the ricefish *Oryzias sarasinorum* (Popta, 1905), the goby *Mugilogobius sarasinorum* (Boulenger, 1897), the sailfin silverside *Telmatherina sarasinorum* Kottelat, 1991, and the gastropod *Sulawesidrobia sarasinorum* Haase & Bouchet, 2006, or alone, as in the coleopteran *Paramblymora sarasini* Breuning, 1961. Their names are also attached to taxa as authors, as for the freshwater gastropod genus *Tylomelania* Sarasin & Sarasin, 1897. As their discoveries came to light in the late 19th and early 20th centuries, the unique role of Sulawesi in evolutionary biology and biogeography was secured.

Endemism of sulawesi's freshwater fishes

Despite the allure of Sulawesi, description of it native fish fauna has been slow and sporadic. There are currently an estimated 56 recognized endemic freshwater fish species known from Sulawesi (Appendix 1), more than double the 25 endemic species listed by Whitten, Mustafa & Henderson (1987: table 4.10).

Noting corrections, including synonymies, and additions to the Whitten, Mustafa & Henderson (1987) list, 25 endemic species were described before 1939, and not another until 1972.

Reports in the aquarium literature of stunning native freshwater fishes, especially in the genus *Oryzias* (e.g., Schrey, 1978), helped reignite interest in the Sulawesi fish fauna beginning in the last quarter of the 20th century. Maurice Kottelat, a Swiss biologist, like the Sarasins, explored Lake Poso and the Malili Lakes in the late 1980s, collected new species and rediscovered and redescribed the endemic Malili Lakes *Oryzias* (Kottelat, 1989a, b, 1990a). The number of endemic species rose abruptly in the early 1990s with his description of 12 new endemic species (Kottelat, 1990 b, c, d, 1991; Larson & Kottelat, 1992). Sulawesi was then reported to have the highest percentage of endemic freshwater fish species among Indonesian islands (Kottelat *et al*, 1993: table 1): 52 endemics out of a total of 68 native species, or 76%. Since 1993, 12 *more* new species have been described and four zenarchopterid species placed in synonymy (Meisner, 2001). The endemic status of some other species is questionable. The wide-spread, well-known *Oryzias celebensis*, for example, has been reported also from Timor (see Parenti, 2008). Even with such corrections, the number of valid native, including endemic, Sulawesi species continues to rise because of focused, intense field exploration and study of archival, museum specimens. Type specimens of the recently described ricefish *Oryzias bonneorum* Parenti, 2008 were collected by entomologists in Lake Lindu (Figure 1) in 1939 as part of mosquito-control studies and held in the Zoological Museum Amsterdam. Their identification as a new species and hypothesis of the species' phylogenetic relationships was made through comparative morphological study, primarily of external anatomy and osteology, without benefit of live color notes. Additional new species of gobies have been identified in collections and await description (Larson, 2001; Hoese & Kottelat, 2005).

Collections over the past two decades have continued to focus on the tectonic lakes: Lake Poso and the Malili Lakes system (e.g., Herder *et al.*, 2006). *Telmatherina albolabiosus* Tantu & Nilawati, 2008, Lake Matano, Malili Lakes, is the first sailfin silverside described since 1991. A new ricefish, *Oryzias hadiatyae* Herder & Chapuis, 2010 was just described from Lake Masapi, also in the Malili lake system. Other regions undoubtedly also harbor new species and should continue to be explored. The Southeast Asian atheriniform family Phallostethidae was unknown from Sulawesi until a 1995 collection uncovered a species living in the Gowa District, Southwestern Sulawesi (Parenti & Louie, 1998). A collection in 2007 from Muna Island by Daisy Wowor, Museum Zoologicum Bogoriense (MZB), revealed the astonishing new *Oryzias woworae* Parenti & Hadiaty, 2010, an endemic species with the most striking live coloration of any known ricefish: adult males and females have a brilliant red and blue color pattern. These specimens have already attracted attention of the aquarium trade. These recent discoveries support the exciting possibility of additional endemic fish species in Sulawesi in all habitats.

Along with discovery of the new species has come understanding that the lakes contain species flocks of adrianichthyids (ricefishes) and telmatherinids (sailfin silversides) and smaller, in number, yet still notable, groups of species of gobiids. Species flocks encourage study of evolutionary patterns and processes and the Malili lakes are fast becoming a popular natural laboratory where hypotheses can be proposed, tested and debated. Introgressive hybridization has been proposed as a factor in the speciation of the Malili lake telmatherinids (Herder *et al.*, 2006). In contrast, ecological specialization and allopatric speciation were proposed as factors driving the speciation of a species flock of Malili lake atyid freshwater shrimps (von Rintelen *et al.*, 2010).

Ricefishes are well known by the medaka, *Oryzias latipes*, an Asian species that is one of the three most popular model organisms among bony fishes (see Parenti, 2008). Sulawesi ricefishes are especially ideal for studies of fish reproduction. *Adrianichthys oophorus* was described as representing a new reproductive guild, pelvic brooders, so named because females hold clusters of fertilized eggs between their pelvic fins and body until hatching (Kottelat, 1990b). Other species may be hermaphrodites (see Parenti, 2008). The endemic ricefishes are a largely untapped resource for evolutionary biological and ecological investigations.

Phylogeny and history of sulawesi endemism

Endemism in Sulawesi fishes is phylogenetically focused. Endemism of freshwater fishes is remarkably well-documented among the atherinomorph orders Atheriniformes and Beloniformes which, together, comprise 44 of the 56 endemics (Table I). Freshwater species of the perciform fish family Gobiidae are represented by ten endemic species in the genera *Mugilogobius, Glossogobius* and *Redigobius,* and the closely related family Eleotridae by one species in the genus *Bostrychus.* A single species of the perciform family Terapontidae completes the list.

Explanations for Sulawesi's high degree of endemism and diversity have emphasized its long-term, complex geological history. Sulawesi lies at the triple junction of the Asian, Australian and Pacific lithospheric plates (Hall, 2002; Villeneuve *et al.*, 2002). The western and eastern parts of Sulawesi are sutured in central Sulawesi, site of the deep, tectonic lake systems. Overlap of the western and eastern portions of the Indo-Australian biota in the southwestern arm of Sulawesi has been demonstrated for several groups of endemic freshwater fishes (e.g., Parenti & Louie, 1998, phallostethids; Meisner, 2001, zenarchopterids) mirroring the distributions of many other taxa in an area of biotic overlap or interdigitation (e.g., Croizat, 1964). But, there are no large-scale comparative biogeographic studies (sensu Parenti & Ebach, 2009, 2010) of the endemic freshwater fish biota that could provide more complex statements of relationships among areas to test geological or climatological histories. These must await further description of taxa, proposals of areas of endemism, and concordant phylogenetic and biogeographic analyses.

Comprehensive surveys of aquatic habitats are necessary to reveal a more detailed and accurate picture of the natural distribution of fish taxa and, therefore, the endemic areas. No ricefishes were reported from North Sulawesi in the preliminary review by Haryono & Tjakrawidjaja (2004), but we hesitate to conclude that ricefishes do not live there. Ricefishes were considered to be restricted to the central part of Sulawesi (see Soeroto & Tungka, 1996); yet recent collections confirm their much broader distribution (e.g., Parenti & Hadiaty, 2010). Coastal areas have been particularly neglected.

Threat of endemic biota

The endemic biota of Sulawesi was acknowledged as threatened just as it was becoming better understood and documented (Whitten, Nash, Bishop & Clayton, 1987). Threats to the biota are well-known. Chief among them is their restricted distribution and habitat specialization, a natural threat to endemics worldwide (De Silva *et al.*, 2007). Human mediated threats are more obvious and include, but are not limited to: flow alteration and water diversion, habitat loss and modification, pollution, introduction of exotic species, and overfishing (see Kottelat, 2002). All of these factors threaten the native fish fauna of Sulawesi, with perhaps pollution and introduction of exotics predominant (see Parenti & Soeroto, 2004).

Introduction of exotic species has been rampant in the tectonic lakes. The number of documented introduced species is staggering. Sixteen exotics were reported by Tantu & Nilawati (2007) from Lake Matano, including the guppy, *Poecilia reticulata*, the common carp, *Cyprinus carpio*, and Mozambique tilapia, *Oreochromis mossambicus*, three species widely introduced worldwide in freshwater habitats. These assaults on the endemic fish fauna have undoubtedly caused the extinction of several species in Sulawesi. The large ricefish or buntingi, genus *Adrianichthys*, endemic to Lake Poso, comprise four species, two of which, *A. kruyti* and *A. roseni,* have not been collected in decades (see materials in Parenti, 2008). A third species, *A. oophorus*, was abundant in 1995 (Parenti & Soeroto, 2004). An adult female *Adrianichthys poptae* measuring 146 mm Standard Length (SL) and 180 mm in total length, was collected on hook-and-line in April, 1991 by Adrian Sigilipu, a local schoolmaster (Figure 2; Soeroto & Tungku, 1991; B. Soeroto, pers. comm.). Published reports indicate that the species was collected as most recently as 2003 (Parenti & Soeroto, 2004). These *A. poptae* specimens are not known to have been deposited in museum collections, which means, unfortunately, that their identification and continued existence in Sulawesi cannot be confirmed.

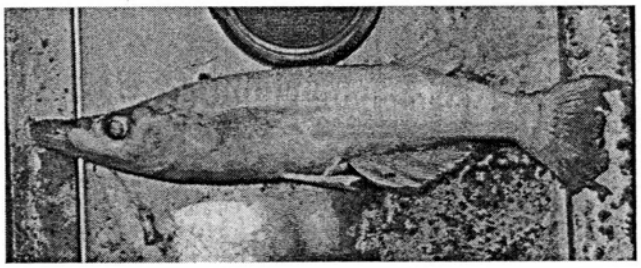

Figure 2. *Adrianichthys poptae*, adult female, 146 mm SL,
Collected 1991 from Lake Poso by Adrian Sigilipu.
Photograph by L. R. Parenti, Manado, Sulawesi, August, 1995.

Summary recommendations

Endemic species are ideal icons to generate national and international interest in and encourage conservation of the endemic freshwater biota of Sulawesi. Its rich natural heritage has long been heralded and is well-understood to be worth conserving for future generations. Ideally, all exotic species would be extirpated and natural habitats returned to their original condition, yet, this is not practical. More important, it is beyond the scope of individual biologists. Recommendations here focus on what can be done now to ensure that more of the native fauna is properly documented and conserved:

Voucher specimens should be deposited in museums worldwide. Natural history collections are our archives of biodiversity on Earth. Representative specimens of all species, especially type specimens, should be deposited in the MZB, Cibinong, and other collections worldwide, as appropriate. Records based on specimens that have not been deposited in a *bona fide* collection cannot be confirmed and are suspect.

Unique role of Sulawesi endemic in studies of evolutionary patterns and processes should be encouraged. Sulawesi is a natural biological laboratory. The unique reproductive and other morphological characters of Sulawesi's endemic fishes can attract worldwide attention. Perhaps the next model organism will come from Sulawesi. Overfishing, especially by the aquarium trade, should be discouraged. Species may be bred in captivity for broad scale distribution to aquaria and laboratories rather than fished out of their natural habitat to elimination.

International collaborations and training programs should be supported. The proper care and preservation of natural history materials requires specialized knowledge that is handed down from generation to generation (see Parenti, 1999). International collaborations will help train the next generation of biologists, collection managers, and policy makers and continue to build and care for natural history collections. Exchange of select materials between Indonesia and other countries will make specimens of these taxa less vulnerable to the ultimate destruction they could possibly face if maintained in just one museum collection. Careful planning and collaboration can ensure that the rich natural history heritage of Sulawesi is appreciated and enjoyed well into the future.

Acknowledgment

I am grateful for the invitation to be a keynote speaker at the Seminar Nasional Ikan VI and Kongres Masyarakat Iktiologi Indonesia III and thank the organizing committee, in particular Renny K. Hadiaty, Cibinong, and Daniel Lumbantobing and his family, for their gracious hospitality during my stay in Indonesia. Travel and other expenses were supported by the Herbert R. and Evelyn Axelrod Chair in Systematic Ichthyology in the Division of Fishes, National Museum of Natural History, Smithsonian Institution, Washington, DC, USA. Bambang Soeroto, Manado, provided information on ricefishes collected in Lake Poso.

Literature cited

Abell, R., M. L. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya, B. Coad, N. Mandrak, S. Contreras Balderas, W. Bussing, M. L. J. Stiassny, P. Skelton, G. R. Allen, P. Unmack, A. Naseka, R. Ng, N. Sindorf, J. Robertson, E. Armjio, J. V. Higgins, T. J. Heibel, E. Wikramanayake, D. Olson, H. L.López, R. E. Reis, J. G. Lundberg, M. H. Sabaj Pérez, & P. Petry. 2008. Freshwater ecoregions of the world: A new map of biogeographic units for freshwater biodiversity conservation. *BioScience*, 5: 403-414.

Boulenger, G. A. 1897. An account of the freshwater fishes collected in Celebes by Drs. P. & F. Sarasin. *Proceedings of the Zoological Society of London*, April 6, 1897:426-429, pl. 28.

Breuning, S. 1961. Einige neue Lamiinae von Celebes aus dem naturhistorischen Museum, Basel. *Verhandlungen der Naturforschenden Gesellschaft im Basel* 72: 120-121.

Collette, B.B. 2004. Family Hemiramphidae Gill 1859 –halfbeaks. *California Academy of Sciences Annotated Checklists of Fishes* number 22, 35 pp.

Croizat L. 1964. *Space, time, form: The biological synthesis*. Caracas: Author.

De Silva, S.S., Abery, N.W., Nguyen, T. T. T. 2007. Endemic freshwater finfish of Asia: distribution and conservation status. *Diversity and Distributions* 13:172-184.

Eschmeyer, W.N. 2010. *Catalog of fishes*. California Academy of Sciences, San Francisco, CA, online database accessed October 21, 2010, at http://research.calacademy.org/ichthyology/catalog/fishcatmain.asp.

Haase, M & Bouchet, P. 2006. The radiation of hydrobioid gastropods (Caenogastropoda, Rissooidea) in ancient Lake Poso, Sulawesi. *Hydrobiologia* 556:17-46.

Hall, R. 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: Computer-based reconstructions, model and animations. *Journal of Asian Earth Science* 20: 353-43.

Haryono & Tjakrawidjaja, A.H. 2004. *Studies on: The freshwater fishes of North Sulawesi*. Bidang Zoologi-Pusat Penelitian Biologi, Lembaga Ilmu Pengetahuan Indonesia, Bogor.

Herder, F., Chapuis, S. 2010. *Oryzias hadiatyae*, a new species of ricefish (Atherinomorpha: Beloniformes: Adrianichthyidae) endemic to Lake Masapi, Central Sulawesi, Indonesia. *The Raffles Bulletin of Zoology* 2010 58(2): 269-280.

Herder, F., Nolte, A.W., Pfaender, J., Schwarzer, J., Hadiaty, R.K. & Schliewen, U.K., 2006. Adaptive radiation and hybridization in Wallace's Dreamponds: evidence from sailfin silversides in the Malili Lakes of Sulawesi. *Proceedings of the Royal Society B* 273:2209-2217.

Hoese, D. F. & Kottelat, M. 2005. *Bostrychus microphthalmus*, a new microphthalmic cavefish from Sulawesi (Teleostei: Gobiidae). *Ichthyological Exploration of Freshwaters* 16: 183-191.

Iskandar, D.T., Nio, T.K., 1996. The amphibians and reptiles of Sulawesi, with notes on the distribution and chromosomal number of frogs. Pp. 39-46. In: *Proceedings of the first international conference on eastern Indonesian-Australian vertebrate fauna, Manado, Indonesia, November 22-26, 1994.*Kitchener, D.J. & Suyanto, A. (eds.). Western Australian Museum for Lembaga Ilmu Pengetahuan Indonesia, Perth, W.A.

Kottelat, M. 1989a. Der Matano-See. *Aquarien und Terrarien Zeitschrift* 42: 616-618.

Kottelat, M. 1989b. Der Towuti-See. *Aquarien und Terrarien Zeitschrift* 42: 681-684.

Kottelat, M. 1990a. Sulawesi: Flussfische. *Aquarien und Terrarien Zeitschrift* 43: 735-738.

Kottelat, M. 1990b. Synopsis of the endangered Buntingi (Osteichthyes: Adrianichthyidae and Oryziidae) of Lake Poso, Central Sulawesi, Indonesia, with a new reproductive guild and descriptions of three new species. *Ichthyological Exploration of Freshwaters* 1: 49-67.

Kottelat, M. 1990c. The ricefishes (Oryziidae) of the Malili lakes, Sulawesi, Indonesia, with description of a new species. *Ichthyological Exploration of Freshwaters* 1: 151-166.

Kottelat, M. 1990d. Sailfin silversides (Pisces: Telmatherinidae) of Lakes Towuti, Mahalona and Wawantoa (Sulawesi, Indonesia) with descriptions of two new genera and two new species. *Ichthyological Exploration of Freshwaters* 1:35-54.

Kottelat, M. 1991. Sailfin silversides (Pisces: Telmatherinidae) of Lake Matano, Sulawesi, Indonesia, with descriptions of six new species. *Ichthyological Exploration of Freshwaters* 1: 321-344.

Kottelat, M. 2002. Aquatic ecosystems: neglected biodiversity. pp. 30-35, In: *Terrestrial ecoregions of the Indo-Pacific. A conservation assessment.* Wikramanayake, W., Dinerstein, E., Loucks, C. J., Olson, D.M., Morrison, J., Lamoreaux, J., McKnight, M. & Hedao, P. (eds.). Island Press, Washington, D.C.

Kottelat, M. & Whitten, T. 1996. Freshwater biodiversity in Asia with special reference to fish. *World Bank Technical Paper* 343, 59 pp.

Kottelat, M., Whitten, A.J., Kartikasari. S.N., & Wirjoatmodjo. S. 1993. *Freshwater fishes of Western Indonesia and Sulawesi.* Hong Kong: Periplus Editions (HK) Ltd. in collaboration with the Environmental Management Development in Indonesia (EMDI) Project, Ministry of State for Population and Environment, Republic of Indonesia. Jakarta.

Larson, H.K. 2001. A revision of the gobiid fish genus *Mugilogobius* (Teleostei: Gobioidei), and its systematic placement. *Records of the Western Australian Museum* Supplement no. 62.

Larson, H. K.& Kottelat, M. 1992. A new species of *Mugilogobius* (Pisces: Gobiidae) from Lake Matano, central Sulawesi, Indonesia. *Ichthyological Exploration of Freshwaters* 3: 225-234.

Meisner, A.D. 2001. Phylogenetic systematics of the viviparous halfbeak genera *Dermogenys* and *Nomorhamphus* (Teleostei: Hemiramphidae: Zenarchopterinae). *Zoological Journal of the Linnean Society* 133: 199-283 .

Musser, G.G. 1982. Results of the Archbold Expeditions No. 110. *Crunomys* and the small bodied shrew rats native to the Philippine islands and Sulawesi. *Bulletin of the American Museum of Natural History* 174:1-95

Myers, N. 1988. Threatened biotas: 'hotspots' in tropical forests. *Environmentalist* 8:1-20.

Parenti, L. R. 1999. *Collective spirit.* [Commentary on] *Collection building in Ichthyology and Herpetology.* 1997. T. W. Pietsch & W. D. Anderson, Jr., (eds.), American Society of Ichthyologists and Herpetologists. *Environmental Biology of Fishes* 55:203-206.

Parenti, L. R. 2008. A Phylogenetic Analysis and taxonomic revision of Ricefishes, *Oryzias* and relatives (Beloniformes, Adrianichthyidae). *Zoological Journal of the Linnean Society* 154: 494-610.

Parenti, L. R. & Ebach, M.C. 2009.*Comparative Biogeography: Discovering and Classifying Biogeographical Patterns of a Dynamic Earth.* University of California Press, Berkeley. 295 pp.

Parenti, L. R. & Ebach, M. C. 2010. Wallacea Deconstructed. Pp. 303-318, In: *Beyond cladistics. The branching of a paradigm.* Williams, D. M & Knapp, S. (eds.). University of California Press, Berkeley

Parenti, L. R., & Hadiaty, R.K. 2010. A new, remarkably colorful, small ricefish of the genus *Oryzias* (Beloniformes, Adrianichthyidae) from Sulawesi, Indonesia. *Copeia* 2010 (2):269-274.

Parenti, L. R. & Louie, K.D. 1998. *Neostethus djajaorum*, new species from Sulawesi, Indonesia, the first phallostethid fish (Teleostei, Atherinomorpha) known from east of Wallace's Line. *Raffles Bulletin of Zoology* 46(1):139-150.

Parenti, L. R. & Soeroto, B. 2004. *Adrianichthys roseni* and *Oryzias nebulosus*, two new ricefishes (Atherinomorpha: Beloniformes: Adrianichthyidae) from Lake Poso, Sulawesi, Indonesia. *Ichthyological Research* 51(1):10-19

Popta, C.M.L. 1905. Note XXII. *Haplochilus sarasinorum*, n.sp. *Notes from the Leyden Museum* 25: 239-247.

Sarasin, P. & Sarasin, F. 1897. Über die Mollusken-fauna der grossen Süsswasser-Seen von Central-Celebes III. *Zoologischer Anzeiger* 539/540: 308-320.

Sarasin, P. & Sarasin, F. 1898. Materialien zur Naturgeschichte der Insel Celebes. I. Die Süsswasser-Mollusken von Celebes. Kreidel Verlag, Wiesbaden.

Sarasin, P. & Sarasin, F. 1905. Reisen in Celebes ausgeführt in den Jahren 1893-96 und 1902-1903, 1. Kreidel Verlag, Wiesbaden.

Schrey, W.C. 1978. Fast schon eine 'Rarität' -Die Gattung *Oryzias*. *Die Aquarien-und Terrarien Zeitschrift* 10: 335-338.

Simpson, G.G. 1977. Too many lines: the limits of the Oriental and Australian zoogeographic regions. *Proceedings of the American Philosophical Society* 121:107-120.

Soeroto, B. & Tungka, F. 1991. Fish fauna, fisheries and Adrianichthyoidei in Lake Poso. In *Phylogeny and species differentiation of Adrianichthyoidei in Indonesia.* Study Report. Monbusho International Scientific Research Program, 12-14.

Soeroto, B. & Tungka, F. 1996. The inland fishes and the distribution of Adrianichthyoidea of Sulawesi Island, with special comments on the endangered species in Lake Poso. In Kichener, DJ, Suyanto, A, eds., *Proceedings of the first international conference on eastern Indonesian-Australian vertebrate fauna, Manado, Indonesia, November 22-26, 1994.* Perth: Western Australian Museum for Lembaga Ilmu Pengetahuan Indonesia, 1-5.

Tantu, F.Y. & Nilawati, J. 2007. The exotic fish and fisheries in Lake Matano South Sulawesi. *Jurnal Agrokultur* 4(7):29-39.

Tantu, F.Y. & Nilawati, J. 2008. *Telmatherina albolabiosus*, a new species of sailfin silversides (Atheriniformes: Telamtherinidae) from Lake Matano, South Sulawesi. *Wallacea, Journal of Biodiversity* 1(1): 20-26.

Villeneuve, M., Gunawan, W., Cornee, J.-J. & Vidal, O. 2002. Geology of the central Sulawesi belt (eastern Indonesia): constraints for geodynamic models. *International Journal of Earth Sciences* 91:524-537.

von Rintelen, K., Glaubrecht, M., Schubart, C.D., Wessel, A. & von Rintelen, T.2010. Adaptive radiation and ecological diversification of Sulawesi's ancient lake shrimps. *Evolution*, published online 22 June 2010: DOI:10.1111/j.1558-5646.2010.01043.x.

Wallace, A. R. 1869. *The Malay Archipelago: The Land of the Orang-Utan and the Bird of Paradise: A narrative of travel, with sketches of man and nature*. Dover Publications, New York [1962 reprint].

Whitten, A.J., Mustafa, M. & Henderson, G.S. 1987. *The ecology of Sulawesi.* Yogyakarta, Indonesia: Gadjah Mada University Press.

Whitten, A.J., Nash, S.V., Bishop, K.D. & Clayton, L. 1987. One or more extinctions from Sulawesi, Indonesia? *Conservation Biology* 1:42-48.

Appendix 1. Endemic Freshwater Fishes of Sulawesi (following Kottelat *et al.*, 1993; Meisner, 2001; Collette, 2004; Parenti, 2008). For authority of species names not cited in the text, see Eschmeyer (2010).

Order Atheriniformes
- Family Telmatherinidae
  - Genus *Marosatherina*
    - *M. ladigesi* (Ahl, 1936)
  - Genus *Telmatherina*
    - *T.* abendanoni Weber, 1913
    - *T. albolabiosus* Tantu & Nilawati, 2008
    - *T. antoniae* Kottelat, 1991
    - *T. bonti* Weber & de Beaufort, 1922
    - *T. celebensis* Boulenger, 1897
    - *T. obscura* Kottelat, 1991
    - *T. opudi* Kottelat, 1991
    - *T. prognatha* Kottelat, 1991
    - *T. sarasinorum* Kottelat, 1991
    - *T. wahjui* Kottelat, 1991
  - Genus *Tominanga*
    - *T. aurea* Kottelat, 1990d
    - T. sanguicauda Kottelat, 1990d
  - Genus *Paratherina*
    - *P. cyanea* Aurich, 1935
    - *P. labiosa* Aurich, 1935
    - *P. striata* Aurich, 1935
    - *P.* wolterecki Aurich, 1935
- Family Phallostethidae
  - Genus Neostethus
    - *N. djajaorum* Parenti & Louie, 1998

Order Beloniformes
- Family Adrianichthyidae
  - Genus *Adrianichthys*
    - *A. kruyti* Weber, 1913
    - *A. oophorus* (Kottelat, 1990b)
    - *A. poptae* (Weber & de Beaufort, 1922)
    - *A. roseni* Parenti & Soeroto, 2004
  - Genus *Oryzias*
    - *O. bonneorum* Parenti, 2008
    - *O. hadiatyae* Herder & Chapuis, 2010
    - *O. marmoratus* (Aurich, 1935)
    - *O. matanensis* (Aurich, 1935)
    - *O. nebulosus* Parenti & Soeroto, 2004
    - *O. nigrimas* Kottelat, 1990b
    - *O.* orthognathus Kottelat, 1990b
    - *O.* profundicola Kottelat, 1990c
    - *O.* sarasinorum (Popta, 1905)
    - *O. woworae* Parenti & Hadiaty, 2010
- Family Zenarchopteridae
  - Genus *Dermogenys*
    - *D.* orientalis (Weber, 1894)
    - *D. vogti* Brembach, 1982
  - Genus *Nomorhamphus*
    - *N.* brembachi Vogt, 1978
    - *N. celebensis* Weber & de Beaufort, 1922
    - *N. ebrardtii* (Popta, 1912)
    - *N. hageni* (Popta, 1912)
    - *N. kolonodalensis* Meisner & Louie, 2000
    - *N. liemi* Vogt, 1978
    - *N. megarrhamphus* (Brembach, 1982)

N. towoetii Ladiges, 1972
N. weberi (Boulenger, 1897)
Genus Tondanichthys
T. kottelati Collette, 1995
Order Perciformes
Family Eleotridae
Genus *Bostrychus*
Bostrychus microphthalmus Hoese & Kottelat, 2005
Family Gobiidae
Genus *Mugilogobius*
M. adeia Larson & Kottelat, 1992
M. amadi (Weber, 1913)
M. latifrons (Boulenger, 1897)
M. lepidotus Larson, 2001
M. rexi Larson, 2001
M. sarasinorum (Boulenger, 1897)
Genus *Glossogobius*
G. flavipinnis (Aurich, 1938)
G. intermedius Aurich, 1938
G. matanensis (Weber, 1913)
Genus *Redigobius*
Redigobius penango (Popta, 1922)
Family Terapontidae
Lagusia micracanthus (Bleeker, 1860)