References

FULLER, R. L., AND R. J. MACKAY. 1980. Feeding ecology of three species of *Hydropsyche* (Trichoptera: Hydropsychidae) in southern Ontario. Can. J. Zool. **58**: 2239–2251.

———, ———, AND H. B. N. HYNES. 1983. Seston capture by *Hydropsyche betteni* nets (Trichoptera; Hydropsychidae). Arch. Hydrobiol. **97**: 251–261.

LABARBERA, M. 1984. Feeding currents and particle capture mechanisms in suspension feeding animals. Am. Zool. **24**: 71–84.

———, AND S. VOGEL. 1976. An inexpensive thermistor flowmeter for aquatic biology. Limnol. Oceanogr. **21**: 750–756.

LOUDON, C., AND D. N. ALSTAD. 1990. Theoretical mechanics of particle capture: Predictions for hydropsychid caddisfly distributional ecology. Am. Nat. In press.

SILVESTER, N. R. 1983. Some hydrodynamic aspects of filter feeding with rectangular-mesh nets. J. Theor. Biol. **103**: 265–286.

TAMADA, K., AND H. FUJIKAWA. 1957. The steady two-dimensional flow of viscous fluid at low Reynolds numbers passing through an infinite row of equal parallel circular cylinders. Q. J. Mech. Appl. Math. **10**: 425–432.

VOGEL, S., AND M. LABARBERA. 1978. Simple flow tanks for research and teaching. BioScience **28**: 638–643.

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Mermaids—their biology, culture, and demise[1]

Abstract—*Siren* L. (Nixi *subordo nova*, Sirenia, Illiger) is redescribed on the basis of hitherto overlooked observations. Three species, essentially restricted to the sublittoral of warm seas, are recognized. Records from higher latitudes are explained as those of wampum-collecting individuals. Biological and ethological data are reviewed and new inferences made about mariculture. The extinction of the group during this century is hypothesized to have been caused by the increase of jellyfish due to reduction of planktivorous visual predators by humans.

Any branch of science advances at a fast pace when enough facts are at hand to permit phrasing of alternative hypotheses which, by requiring testing, lead to an organized search for more facts, be it by field observations or controlled experiments. Hypotheses are continually erected, then torn down, but the latter process often results in perfectly good data being buried among masses of rejected material. Paraphrasing von Stosch (1964), the present edifice of scientific knowledge rises over heaps of earlier observations, like modern cities at sites of antiquity grow upon hills of much rubble. As archaeology has shown at these sites, however, sorting the ancient wheat from the chaff can be highly rewarding. Obviously, a hypothesis guiding a dig will lead to more success than random probing, but archaeology—or history as a scholarly discipline—differs from the natural sciences because controlled experimentation for testing hypotheses is usually not possible at such sites—there is only one Layer VII A at Troy. Worse yet, the searched-for treasure may be broken and salient pieces missing. Thus, reconstruction requires not only solid training in subject matter and critical attitude but also imagination and sometimes daring. In modern science, though, imagination is often discouraged by present-day scientific journals for lack of space, stifling full discourse on alternative but untestable interpretations of observations (cf. Gould 1980).

My note, by the nature of the data, is situated between science as it normally should, and archaeology or historical work as it often must, be conducted. It is critical but also daring, setting out from an anatom-

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ical observation about mermaids that Linnaeus (1758) cited but was afraid to pursue, thereby being buried under the progress of science. *My hypothesis is that mermaids should be taken seriously.* Regrettably, I have to look for facts for supporting the hypothesis rather than resort to evidence for falsifying it—but at least at the end of this note I will make a suggestion for follow-up work that requires methodology more in tune with present near-dogma for the conduct of scientific inquiry derived from the discourses of Popper (1976).

Linnaeus's (1758) system of Mammalia started with Man as the crown of creation; in about the middle of the class, the music-loving manatee (later in Sirenia) was put next to the armadillo and similar animals (later in Xenarthra or Edentata); it concluded with the toothed whales. Tacked onto the class as a three-line footnote was *Siren,* based on the mention in the literature of a specimen from Brazil, kept in the museum at Leyden. Linnaeus regarded the creature as "paradoxical" and *incertae sedis* "because of its large ears and a neck which is rare in marine mammals," not realizing that sea lions do possess external ears. Cuvier (1831) delegated the genus to Amphibia (within Reptilia) in spite of the ears, but a later picture of the type specimen (Fig. 1) clearly shows its mammalian character.

Fig. 1. The Brazilian specimen of *Siren indica* on exhibit in Leyden (from Landrin 1877).

The generic mermaid possessed binocular vision and forelimbs with opposable thumbs. Perhaps connected with these characters, a well-developed cerebrum is suggested by the large forehead, clearly visible in all pictures. The hindbody lacked external limbs, and the end usually was drawn with rays as in fishes, but actually it was a homocercal fluke (cf. Henry Hudson's log, *cited by* Purchas 1625). As with the fishy tail, the common depicting of scales covering the entire hindbody was caused, of course, by the artists never having seen specimens; truly, the "scales" were more or less distinct horny skinfolds similar to those in some of the Xenarthra. Further, the animals lacked the blubber of the standard marine mammal, explaining why they principally inhabited warm waters. Finally, I infer from the many figures that the hairless skin of the body was thin, an observation figuring prominently in the hypothesis (below) about the demise of the creatures.

At present, three species (possibly with subspecies) can be distinguished; they are to be described in detail in a treatise, including all synomyms and plesionyms, as well as geographic distribution (in prep.). Briefly, the type species, *Siren sirena,* with a Mediterranean-Lusitanian distribution, has been reported literarily since antiquity but never named. For ease of communication, a *nomen nudum* (*see also under culture*) is introduced here for the species, as also for the new suborder Nixi that is juxtaposed to Manati *mihi* (with manatees, dugongs, and the extinct Steller's sea cow). *Siren indica,* observed first off St. Domingo on the third voyage of Columbus and restricted to the Atlantic side of the Americas, was named by the naturalist C. S. de Nereus who died on the return trip, leaving only a hand-written diary. Since his binomen predates the 10th edition of Linnaeus (1758), a special ruling must be requested from the

International Commission of Zoological Nomenclature, asking for treatment analogous to that of some of the names of Pallas. The nominate subspecies of *Siren erythraea,* which occurred in the Red and Arabian Seas, as well as in the Indonesian archipelago, was briefly studied by Schlemihl during his work in Nubia (fide von Chamisso 1814). Each species was basically restricted to coastal waters of warm seas; all avoided freshwater. For several regions, e.g. off Arabia and southwest India for *S. erythraea,* it is unclear whether the patchy occurrence reflected scant records or a disjunct distribution caused by upwelling of cold water. Significantly, mermaids did not inhabit the large subtropical upwelling regions of the other oceans. The sightings during summer in cool-temperate regions, even in the open sea, will be explained later.

The biological traits of the three species were similar. For example, *S. sirena* and *S. erythraea* differed principally in the way the females held the suckling young out of the water. For understanding the population dynamics and cultural traits of the Nixi, it suffices to focus on the European *S. sirena.* It is the best-researched species. Nevertheless, evaluation of the literature is confounded by the female Nixi having become paradigms of deviations from the righteous path designated by the medieval church, especially with respect to lust of the flesh (Benwell and Waugh 1965). Hence, most writings seem to mix true beliefs, facts, superstitions, or fears with wishful thinking or free-wheeling imagination, as is also evident from innumerable flawed renderings of mermaids in frescoes in naves or reliefs on pews and bench-ends in churches. Many pictures also adorned nautical charts; considering that the map makers relied on reports by sea captains who by the nature of their trade had to be keen observers, it is surprising that the scale convention for the hindbody was so enduring. Clearly, too much imagination and insufficient critical attitude were applied by the artists to the subject; perhaps the desire to make the creatures remote from Man came also into play. As an example of another kind of bias in reporting, a seemingly accurate picture in a church, like fishes held by mermaids and identifiable at least to family, need not indicate food preferences but may allegorically depict Christian souls snared by *Siren* (Benwell and Waugh 1965). Conversely, it is possible that facts about mermaids that deviated from the canon were not always freely stated in the literature: In France, even in the time of Linnaeus, Diderot and his coworkers on his *Encyclopédie* had to be circumspect when dealing with—to us, innocuous and mundane—observations about nature (Friedenthal 1969). Therefore, could it be that the strange sex ratio in the records (very few mermen) was in part an artifact of reporting, somehow related to the similarly strange but factual ratio of female to male witches burned at the stake even in postmedieval times (about 50 : 1, Friedenthal 1969)?

Regarding mermaid behavior, a recurrent theme is the habit of the females to haul out on beaches (usually in pairs) allegedly to lure, then seduce sailors; their voices were repeatedly recorded as being "irresistible" (so García Márques 1986 for *S. indica*; cf. Zemlinsky 1905). Perhaps they lured—but the stark fact was that they then drowned the men and devoured their flesh. Similarly, when ships broke up in gales, the females pulled sailors down into their abodes for further disposition (Andersen 1836).

With regard to reproduction and associated behavior, we are on relatively firm ground. With two mammary glands, the females probably bore one young and occasionally two at a time. As the adult weight of at least the European species was somewhat less than that of Man (many observations), the gestation time as well as the age at first maturity can be fairly reliably estimated by allometric rules to have been 165 d and 3–4 yr, respectively (*see* Peters 1983, appendix 8). Some notes about the young and adolescents can be found in Andersen (1836). Also, I believe that the young of all species were particularly sensitive to predation because of their size. Considering the brain size and the social organization of the Nixi (Andersen 1836), I wonder whether the young were held in nurseries and protected by some structure built from driftwood, coral blocks, and the like (cf. the shallow-water data on "baby-sitting" by the

similarly large-brained dolphins, Booth 1988). Nothing of these edifices, of course, remains since preservation in the physically highly energetic inshore environment is almost impossible. Moreover, marine transgression since the end of the ice age has submerged everything. The same holds for prehistoric human settlements on the present continental shelves—we do not have skeletons from the area now covered by the sea, although at least some sites of settlement are documented by accidentally dredged-up implements.

The lack of skeletons and, hence, of size-frequency statistics for mermaid populations entails that their mortality patterns (whence, life expectancy) are not known. Therefore, population dynamics and densities cannot be determined on this basis even if we were to guess reasonably well the time between pregnancies from allometry and combine it with age at first maturity. Alternatively, using somewhat different allometric reasoning and considering food-chain efficiency, Sheldon and Kerr (1972) calculated the numbers of monsters Loch Ness could support, i.e. their population density. Difficult as this method would be for omnivores like the Nixi that competed with a host of other species of unknown abundance for the same food base, it cannot be used to estimate population sizes because of the likelihood of mariculture by *Siren*.

In considering the culture of mermaids, two facts of life in the marine realm—the lack of fire (hence, no pottery or metallurgy) and the absence of fibers suitable for basketry, clothing, or ropes—must be considered. Thus, in spite of the propitious anatomical base of hands and large brains, the only development possible for mermaids was an analog to a very early human stone-age culture. Clearly, though, the physical want did not preclude a relatively advanced socio-political structure (cf. Andersen 1836). Therefore, Nixi must not be thought of as mere hunters and gatherers but as farmers cultivating shellfish and sea grasses, with the organizational and political stability needed for allocating plots and enforcing the assignments. Their mariculture must have constrained the locations of dense mermaid populations: Almost without exception, such food species can be raised in quantity only in reasonably protected sandy or muddy areas. As with the nurseries, however, all traces of mariculture have been erased by the postglacial transgression. Had there been pottery, at least the sites of settlements might be found (and even dated!).

Turning now to communications and trade, from Andersen's writing and the above supposition about mariculture, combined with the nature of most low-latitude coastlines, we might visualize areas or provinces with rather dense populations and appreciable political organization, separated by rocky or very exposed sandy stretches that were frequented only during food-gathering or hunting expeditions, if at all (of course, even such limited activity would have altered those hard-bottom communities greatly). Communication between the population centers could have been by messengers or underwater sound, presumably generated with bell stones or the like. Next, given differing natural resources in the various chiefdoms, it is perhaps not too far-fetched to think of some trade, not in staple foods because of the difficulty of hauling over large distances through rough waters, but in rare commodities, such as slaves for working the fields. While barter agreements leap to mind first, trade using proper currency should not be dismissed out of hand. In fact, the need for "coins," in the absence of pottery or metal, explains most easily the sightings during summer in high latitudes (e.g. in the Barents Sea, at 75°N by Henry Hudson, cf. Purchas 1625; inner Danish waters, Andersen 1836): As with the wampum of North American Indians (and metallic tender in general), coinage not only must have an agreed-upon value but also must not be struck by everybody. Social taboos having nowhere prevented forgery and fraud, what easier method of restricted "minting" would there be for warm-water species than using shells of polar molluscs, collected in the far north or in the so much more pleasant settings of the southern exit of the Øresund and off southern Sweden (for the so-called glacial relics of the Baltic, cf. Ekman 1935)? It is now hopeless, of course, to look for fossil traces of such trade in the warm seas. Once the *raw* shells ceased to be

used as tender and were worked before payment (broken in some manner, as with wampum), these needles in hay stacks, i.e. in shell beds, became indistinguishable from indigenous broken material.

Addressing, finally, the demise of mermaids and the possible causes, with fossils or estimates of population density by other methods lacking, we are dependent on records of sighting that are difficult to quantify. No conjecture, therefore, is possible about the effect on mermaids of the arrival of prehistoric man, which in, for example, the Americas was catastrophic for so many of the big terrestrial mammals. Since Steller's sea cow became extinct in the 18th century (perhaps only in the early 19th, cf. Brehm 1900) as a result of its oil and tasty flesh, and manatees are also eaten by people, sireniids perhaps were hunted early on. Later, medieval records do not speak to that practice. In any event, the number of recorded sightings began to decline after the Age of Discovery and, as far as can be ascertained, fell to zero at some time in this century. The decline could have been caused by bias in observation and reporting, as well as by actual diminution of numbers and final extinction, the latter having occurred perhaps as late as after World War 2. Presumably, both factors were at work initially. For example, introduction of more efficient sailing vessels moved trading routes away from the shores—a trend greatly accelerated after the advent of steamships. Also, an increasing bias in reporting may have arisen, first (i.e. since the Period of Enlightenment) only for fear of ridicule but later from the "weeding" action by editors of scholarly journals who more and more are among the guardians of Science as the new faith. These prejudices, however, are unlikely to have distorted the truth totally. I conclude from the absence of recent records that mermaids did disappear.

Some possible causes of extinction of all three species can be dismissed rather easily. Hunting on a broad scale would not have escaped notice, and large-scale starvation is improbable since the potential food resources in the lower latitudes are not known to have changed drastically during the period at issue. Instead, the cause must have been a change, affecting the mermaids specifically, that was caused by, or correlated with, human technology intruding the marine arena since the later decades of the last century. I hypothesize that the cause was the increase of mechanized fishing, which, outside the northern temperate waters, was often preceded by fishing with dynamite (e.g. at the beginning of this century in Melanesia, cf. London 1913). The resulting removal of planktivorous visual predators (principally finfishes) shifted the ecological balance of open waters toward invertebrate predators, including jellyfish (*see* Landry 1977 for the mechanism). Because mermaids had thin skin and no access to clothing, they were helpless, especially at night, against the stings of jellyfish.

Regrettably, it is not known whether jellyfish, especially the dangerously poisonous forms, have broadly increased since the later decades of the 19th century. For decades, planktologists, starting quantitative work just at that time (Hensen 1887), routinely threw away catches containing jellyfish because the copepods and diatoms could not be counted in such hauls. Only since the recent advent of scientific SCUBA diving (e.g. Hamner et al. 1975), which also removed the double handicap of destruction of gelatinous animals by the collecting gear and the preservative, have we realized the importance of these animals. Since then, there have been more and more records of mass occurrences of jellyfish (e.g. Legović 1987; Möller 1980).

Although decades have thus been wasted, the hypothesis about the cause of the mermaids' demise can still be tested. Jellyfish carry as commensals amphipod crustaceans which often stray from their hosts and are caught in plankton nets. They have been well studied for some regions of the open ocean (e.g. Shulenberger 1979), but vast museum collections, dating back to the comprehensive national oceanographic expeditions of the late 19th and early 20th centuries (i.e. the period at issue) and later from time series at shore stations, have been worked up only with respect to taxonomy, if at all. A study of changes of abundance in these samples, coupled with an attempt to normalize the numbers to a standard net

haul (cf. Friedrich 1950), should answer the question about the role of jellyfish in *Siren*'s extinction. Thus, with a clear null hypothesis, mermaid research would cease to be a subject of historical interest only and be brought into tune with the modern, nondescriptive conduct of scientific inquiry.

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References

ANDERSEN, H. C. 1836. Den Lille Havfrue, p. 11–28. *In* P. Borum [1984 reprint ed.], The little mermaid. Brøndum.

BENWELL, G., AND A. WAUGH. 1965. Sea enchantress. Citadel.

BOOTH, W. 1988. The social lives of dolphins. Science **240:** 1273–1274.

BREHM, A. E. 1900. Brehms Tierleben. Die Säugetiere. V. 3, revised ed. Bibliogr. Inst. Leipzig.

CHAMISSO, A. VON. 1814. Peter Schlemihl's wundersame Geschichte. Schrag.

CUVIER, F. 1831. The animal kingdom. V. 2. [Transl.] Carvill.

EKMAN, S. 1935. Tiergeographie des Meeres. Akad. Verlagsges. Leipzig. [English ed., 1953.]

FRIEDENTHAL, R. 1969. Entdecker des Ich—Montaigne, Pascal, Diderot. Piper.

FRIEDRICH, H. 1950. Versuch einer Darstellung der relativen Besiedlungsdichte in den Oberflächenschichten des Atlantischen Ozeans. Kiel. Meeresforsch. 7(2): 108–121.

GARCÍA MÁRQUES, G. 1986. El Amor en los Tiempos del Cólera, 4th ed. Sudam.

GOULD, J. C. 1980. Introduction, p. xi–xix. *In* B. Kurtén, Dance of the tiger. Pantheon.

HAMNER, W. M., L. P. MADIN, A. L. ALLDREDGE, R. W. GILMER, AND P. P. HAMNER. 1975. Underwater observations of gelatinous zooplankton: Sampling problems, feeding biology, and behavior. Limnol. Oceanogr. **20:** 907–917.

HENSEN, V. 1887. Über die Bestimmung des Planktons oder des im Meere treibenden Materials an Pflanzen und Tieren. Komm. Unters. Dtsch. Meere in Kiel 5th Ber., 12–16 Jahrg., p. 1–107.

LANDRIN, A. 1877. Les monstres marins, 3rd ed. Hachette.

LANDRY, M. R. 1977. A review of important concepts in the trophic organization of pelagic ecosystems. Helgol. Wiss. Meeresunters. **30:** 8–17.

LEGOVIĆ, T. 1987. A recent increase of jellyfish populations: A predator-prey model and its implications. Ecol. Model. **38:** 243–256.

LINNAEUS, C. 1758. Systema naturae. V. 1. Regnum animale, 10th ed. Salvius.

LONDON, J. 1913. Mauki. [*In* J. London, South Sea tales, p. 81–118. 1985. Mutual.]

MÖLLER, H. 1980. A summer survey of large zooplankton, particularly scyphomedusea, in North Sea and Baltic. Meeresforschung **28:** 61–68.

PETERS, R. H. 1983. The ecological implications of body size. Cambridge.

POPPER, K. R. 1976. Logik der Forschung, 6th ed. Mohr.

PURCHAS, S. 1625. Purchas his Pilgrimes. Part 3, p. 566–611. Fetherstone.

SHELDON, R. W., AND S. R. KERR. 1972. The population density of monsters in Loch Ness. Limnol. Oceanogr. **17:** 796–797.

SHULENBERGER, E. 1979. Distributional pattern and niche separation among North Pacific hyperiid amphipods. Deep-Sea Res. **26:** 293–315.

STOSCH, H. A. VON. 1964. Zum Problem der sexuellen Fortpflanzung in der Peridineengattung *Ceratium*. Helgol. Wiss. Meeresunters. **10:** 140–152.

ZEMLINSKY, A. 1905. Die Seejungfrau (Sinfonische Dichtung). [1987 reprint ed.] RIAS/DECCA.

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