Coolabah, Nr 34, 2023, ISSN 1988-5946. Online journal of the Observatory: Australian and Transnational Studies Centre (CEAT), University of Barcelona

Nessie and Noctilucent Clouds: A Meteorological Explanation for Some Loch Ness Monster Sightings

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Abstract: Since the 1930s there have been over a thousand recorded sightings of monsters in Loch Ness, Scotland. The consensus of experts is these reports of mysterious creatures (known in Scottish Highlands folklore as Nessie) have mundane or prosaic explanations such as hoaxes, wakes, mirages, misidentifications of floating objects (e.g., natural debris, boats) and known native fauna (e.g., deer, otters, diving birds), opposed to extraordinary or unusual explanations such as exotic fauna, escaped animals from traveling circuses, relict plesiosaurs and unknown or elusive species (e.g., 'long-necked' pinniped, giant eel). After providing an overview of the different hypotheses and a history of the search for the Loch Ness Monster – the author of this paper argues a rare meteorological phenomenon might explain some monster sightings in the loch during twilight hours between May and August – reflections of noctilucent clouds (NLCs).

Keywords: Noctilucent clouds, Loch Ness Monster, Reflections, Atmosphere, NLCs

Introduction

Eyewitness accounts of monsters in Loch Ness, Scotland are traceable in literature as far back as the 1930s and continue to be documented, albeit infrequently.[i] The *Life of Saint Columba* written in the late 7th century CE by Adomnán describes an Irish monk named Columba having encountered a "water beast" (*aquatilis bestia*) in the River Ness (Borsje, 1994). Although often mentioned in books on the putative Loch Ness Monster (Dinsdale, 1973: 25-30; Witchell, 1989: 14), Columba's sighting should be excluded because the River Ness is separated to Loch Ness by another lake, Loch Doufour (Binns, 1984: 52-53).[ii] The sighting itself is not trustworthy; Adomnan wrote his biography of abbot Columba about a hundred years after he died (meaning it is far removed from a first-hand account) and the water beast anecdote appears in the context of miracles, which hardly lends credence to the story.[iii] While a few dozen Loch Ness Monster

reports are dated to the late 19th or beginning of the 20th century, they were not recorded until the 1930s and their reliability is doubtful,[iv] for example, an eyewitness came forward in 1934 and said he observed a monster in the loch more than 60 years earlier but could not remember the exact year (either 1871 or 1872) and was rather vague in his description (Whyte, 1957: 27). In May 1933, the *Inverness Courier* published the first article on a monster sighting in Loch Ness (Campbell, 1933).[v] Scottish newspapers continued to print articles on subsequent reported sightings of large mysterious creatures in the loch and a year later there were at least 43 first-hand eyewitness reports (Burton, 1961: 21) which prompted the book *The Loch Ness Monster and Others* to be published by Rupert T. Gould (a navy officer and investigator of sea-serpents).

Descriptions of monsters in Loch Ness by eyewitnesses in 1933-1934 considerably varied but the national newspaper *The Scotsman* in October 1933 published articles under the title "Loch Ness Monster…" (Stalker, 1933a, 1933b), a name quickly adopted by tabloids in England, as well as books (Oudemans, 1934; Gould, 1934); reports of monsters in Loch Ness, some with little in common were visualised as a single monster type, either one individual (Gould, 1934: 121) or a small family (Carruth, 1938: 14). The putative monster became known locally in the Inverness area and Scottish Highlands folklore as 'Nessie' (from *Niseag* in Scottish Gaelic). In December 1933, the *Daily Mail* published a sensational headline, "Monster of Loch Ness is not a Legend but a Fact" (Binns, 1984: 28) based on some mud tracks found on a bank of the loch (purported to have been left by an elusive creature). However, these mud tracks were soon revealed to be a hoax.[vi] Around the same time, photographs (of rather poor quality) began to circulate of what was said to be the monster. The earliest photo of the Loch Ness Monster by a man named Hugh Gray in November 1933 is probably a swan (Naish, 2017: 95-96), although this is not conclusive given its ambiguity.[vii] The infamous 'Surgeon's photograph' published in the *Daily Mail* (April 1934) is almost certainly a hoax; Martin and Boyd (1999) convincingly argue it was a toy submarine fitted with a fake head to look like a sea-serpent. Repeated hoaxes resulted in national newspapers decreasing quantity of articles they published on the putative monster primarily because of embarrassment (Bauer, 1986: 36-37) and public interest in the Loch Ness Monster too waned; in the mid-to-late 1930s and 1940s sightings did not stop to be recorded but they were considerably less frequent than in 1933 and 1934. It has been argued monster reports were most frequent in 1934 because an expedition attracted more observers to the loch that single year[viii] (Mackal, 1976: 85) and in 1933, the felling of trees plus construction work on a road next to the loch somewhat improved visibility for observers who were driving.

In 1951 there was a minor resurgence of public interest in Nessie when Lachlan Stuart a forestry worker, took a photo of three humps in the loch close to Urquhart Castle. Despite Stuart's photo was a hoax using bales of hale (Witchell, 1989: 83) it took decades to prove this; the photo in the 1950s and 1960s was considered by some investigators to be the best piece of evidence for the putative monster. Stuart's photo was notably reproduced in Constance Whyte's book *More Than a Legend: The Story of the Loch Ness Monster* (Whyte, 1957). The idea of a surviving plesiosaur in Loch Ness predated Whyte's book (Gould, 1934: 119-124), but it faced objections and difficulties she tried to resolve.[ix] In 1959, the zoologist Maurice Burton read Whyte's book and changed his mind from arguing the Loch Ness Monster is an elusive giant eel, to a relict plesiosaur (Tucker, 1960). However, less than two years later he became a lot more sceptical, arguing most monster sightings (90%) can be explained by gas-propelled rotting vegetation or natural debris rising from the loch bottom to water surface, as well as misidentified common objects and known animals (Burton, 1961: 170). In 1961, the engineer turned Nessie-hunter, Tim Dinsdale, published *Loch Ness Monster,* arguably which remains to date the most popular book on the putative monster; the book went through four

editions (Dinsdale, 1961, 1972, 1976, 1982). Dinsdale himself thought he had captured the monster on film in 1960; however, photo stills in his book show nothing of the kind because they are unclear. Campbell (1986a, 2002: 48) interprets Dinsdale's film to show a motor-powered dinghy and wake but this is disputed by others (Bauer, 2002: 236). In 1962, the Loch Ness Investigation Bureau (LNIB) was created; its founding members included Whyte, ornithologist Peter Scott, and politician David James. LNIB carried out photographic surveillance and used sonar technology for underwater searches but repeatedly failed to provide any reliable evidence for an unidentified creature in Loch Ness.

In 1965, the biochemist and zoologist Roy P. Mackal was appointed scientific director of LNIB. His approach to Nessie was different than Gould's and Dinsdale's in the sense he attempted to explain how monsters with an average length of 20-feet could survive and thrive in Loch Ness. To avoid extinction there must be a minimum viable breeding population of 'Nessies' (in their dozens or hundreds) not a single individual or small family (i.e., 2 or 3) as Gould and Dinsdale argued respectively.[x] Mackal (1976: 201) described the concept of there being only one living individual monster (or very few) in the loch absurd and ignorant of population biology; LNIB's literature too stressed "what we are investigating is a breeding herd" (James, 1970). Mackal's credentials and scientific rigour brought respectability to the Nessie hunter community that was previously lacking in the same way Grover Krantz did to the bigfoot community in the 1970s (Regal, 2008). Gould and Dinsdale struggled to explain how food in Loch Ness could viably sustain a population of large unknown creatures. Mackal (1976) ingeniously tried to solve this problem by arguing Nessies could have fed on migrating salmon or eels (but his calculations were overestimations). In his book *The Monsters of Loch Ness,* Mackal estimated that 10% of documented monster sightings in Loch Ness were of an unidentified giant amphibian but 90% misidentifications of known local fauna (e.g., diving birds and swimming deer), boat wakes, floating logs as well as hoaxes (Mackal, 1976: 200-201). The LNIB disbanded in 1972 but its research was continued by the Loch Ness and Morar[xi] Project set up by naturalist Adrian Shine (Shine, 2006: 17) which focused on studying the limnology of Loch Ness (Shine, preferred to carry out scientific investigations at Loch Morar because its water is clearer). In 1972 and 1975, underwater photographs were published, allegedly showing the Loch Ness Monster (Rines et al., 1976). However, some were supposedly retouched; this altered the photos to the extent they bore little resemblance to original photographs (Razdan and Kielar, 1984-1985; Naish, 2013).

In the late 1970s, "Nessie's public respectability declined again" (Bauer, 1986: 164). Mackal by the 1980s seems to have lost interest in the putative monster.[xii] Henry Bauer, author of *The Enigma of Loch Ness* continued where Mackal left off. Like Mackal, Bauer (who holds a PhD) brought academic credibility to the Nessie community, which was lacking; his book on Nessie was published by a reputable university press (Bauer, 1986). Bauer has long argued in terms of population biology and ecology the loch can sustain a breeding population of large elusive creatures and to explain how Nessies entered the loch he claims Loch Ness formerly was a salt-water fjord.[xiii] Bauer has a personal belief in the putative monster but as a scientist he realises limitations of anecdotal eyewitness testimony and "vague photographs or transitory blips on a sonar" (Bauer, 1986: 53). The same year Bauer published his magnum opus on Nessie, another book titled *The Loch Ness Monster: The Evidence* reached the opposite conclusion, "there is absolutely no reason why anyone should believe in the existence of lake monsters" (Campbell, 1986b: 116). This is not the seminal sceptical publication on Nessie; this honor goes to Ronald Binns' book *The Loch Ness Mystery Solved* published in England in 1983 and reprinted in the US a year later (Binns, 1984). Over thirty years later, Binns (2017: 13-14) commented his book "transformed conventional belief in monsters into wider scepticism". This is probably not an overstatement. At the very least Binns' book put to rest the plesiosaur hypothesis. By the 1990s

eyewitness accounts of the Loch Ness Monster dropped to single digits (and in 2009 only one monster sighting was recorded[xiv]). The British Broadcast Corporation in 2003 sponsored a team to search Loch Ness using sonar and satellite technology but results produced "no signs of any large animal living in the loch" (Nickell, 2006: 23). The situation remains the same today and arguably the absence of evidence for so many years has become evidence of absence. Books, articles, and documentaries nevertheless continue to be published on the Loch Ness Monster.[xv]

Hypotheses of Loch Ness Monster sightings

Paxton and Shine (2016) have usefully compiled eighty hypotheses of the Loch Ness Monster (there are many different explanations for reported sightings and photos). These can be divided for convenience into two categories: (1) mundane, or prosaic (common) and (2) extraordinary, or unusual. The former boring explanations include misidentifications and misperceptions by eyewitnesses of known fauna in the loch (swimming deer, diving birds, otters, fish etc), floating natural or artificial debris, wakes from motor-powered boats, hallucinations, mirages, optical illusions, and hoaxes. Combined, these undoubtedly explain a very large percentage of monster reports.[xvi] Dinsdale on one occasion thought he spotted a monster 300-yards from the shore of the loch, but when he checked with binoculars, realised the "monster" was a floating tree-trunk (Binns, 1984: 110). Eyewitnesses on the loch's bank are seldom at close distance to what they report observing in the water, so it is not surprising misidentifications of ordinary animals and floating objects are often made.[xvii] Shine (1993) tested perception accuracy of 36 eyewitnesses from 150 meters (approximately 500-feet) by asking them to describe or draw from memory a wooden post in the loch; roughly a third of the observers (31%) "retained impressions at some variance with the 45 cm straight-sided post". A similar experiment in 2003 with a fencepost at a long distance resulted in some eyewitnesses drawing "monster-shaped heads" (Nickell, 2006: 23). Both these tests used motionless objects; had they used something moving it would have increased the misidentifications by eyewitnesses. The Loch Ness Monster is usually described in eyewitness reports as non-stationary e.g., out of 170 eyewitness reports by LNIB in 1973, 109 (64%) involved motion with an average speed of 7 mph (Willums, 1976). There are other factors[xviii] which can affect the reliability of eyewitness testimony, meaning accuracy of monster sightings (Akins, 1977: 31-41; Campbell, 2002: 12-13; Loxton and Prothero, 2013: 159-164). Observation conditions (for example weather) and duration of sightings are important. Mackal (1976: 88) realized "most observations are brief" and some are glimpses lasting seconds; about a third of sightings recorded by the LNIB in 1973, lasted less than one minute (Willums, 1976).

It goes without saying, not all eyewitnesses are honest.[xix] Hoaxes of the putative monster in the loch have been documented since the 1930s and these continue to the present day; two notable hoaxes took place in 2003 and 2005 (Nickell, 2006: 14-15). Most eyewitnesses, however, are not involved in wilful deception but unintentionally misidentify or mistake what they reported seeing. This is not surprising when it is realised few observers have specialist knowledge of the loch's fauna and are quite inexperienced. It is remarkable virtually no zoologists or marine biologists who travel to Loch Ness report ever seeing the Loch Ness Monster.[xx] James (1968: 21) naively claimed status or credentials of monster eyewitnesses such as "monks, two doctors, a surgeon, a vet […] a youth hostel warden, a local landowner, three gamekeepers and the local water bailiff", meant these observers could not have been mistaken about Nessie's identity but none of these professions equate to expertise in the loch's fauna. There is no reason to think a veterinarian (who specialise in domestic pets and farm animals) will have a particularly good

knowledge of otters, waterfowl, etc. Furthermore, the water bailiff at Loch Ness in the 1930s even mistook the monster for "a line of cormorants floating on the water" (Gould, 1934: 113). In 1962, an expedition to Loch Ness reported 16 mistakes where eyewitnesses had confused mundane or prosaic phenomena for the monster: "8 were wake effects, 6 were birds, one was an otter and one salmon" (Campbell, 2002: 10). Natural debris such as floating logs can explain misperceptions of Nessie and this is the most obvious prosaic explanation (Gould, 1934: 106-108; Binns, 1984: 182). The surfacing wreckage of a German airship shot down during First World War over Loch Ness might have resulted in Nessie misidentifications (Ley, 1966: 236).

Misperceptions of known animals, floating debris and boat wakes have been recognized by many eyewitnesses themselves who realised their own misidentification errors (Mackal, 1976: 83-84; Bauer, 1986: 6-7; Shine, 2006: 12-13; Loxton and Prothero, 2013: 160). Wakes are "V"-shaped wave-patterns moving objects in the water such as boats and waterfowl create; Binns (1984: 183) notes "It can take up to twenty minutes for a wake to reach the shore, by which time the boat creating it has long passed out of sight". Arguably, the dullest of all explanations for eyewitness accounts of the Loch Ness Monster are hallucinations, which result from mental illnesses, sleep deprivation or alcohol-induced psychosis; it has long been joked, "sea serpents are seen not far from scotch whisky distilleries" (Wilkins, 1948: 15) . Mackal (1976: 84-85) disregarded three eyewitnesses from his list of recorded sightings because they suffered from mental disorders, presumably causing them to hallucinate. Shine was recently quoted as saying he estimates 70% of sightings are boat wakes, 20% mistaken known birds and 10% "everything else – logs and whatever" (Teeman, 2020). Bauer who is a believer in Nessie as an unknown animal nevertheless agrees with foremost sceptics such as Binns and Shine, that "At Loch Ness the opportunities to be deceived are legion" (Bauer, 1986: 56). Similarly, cryptozoologist Loren Coleman has been quoted as saying "From a distance just about anything might look like a lake monster" (France, 2019: 173). A pictorial montage of these sources of deception in Loch Ness was created by Shine (see Fig. 1). There are other prosaic explanations.[xxi] Otters undoubtedly

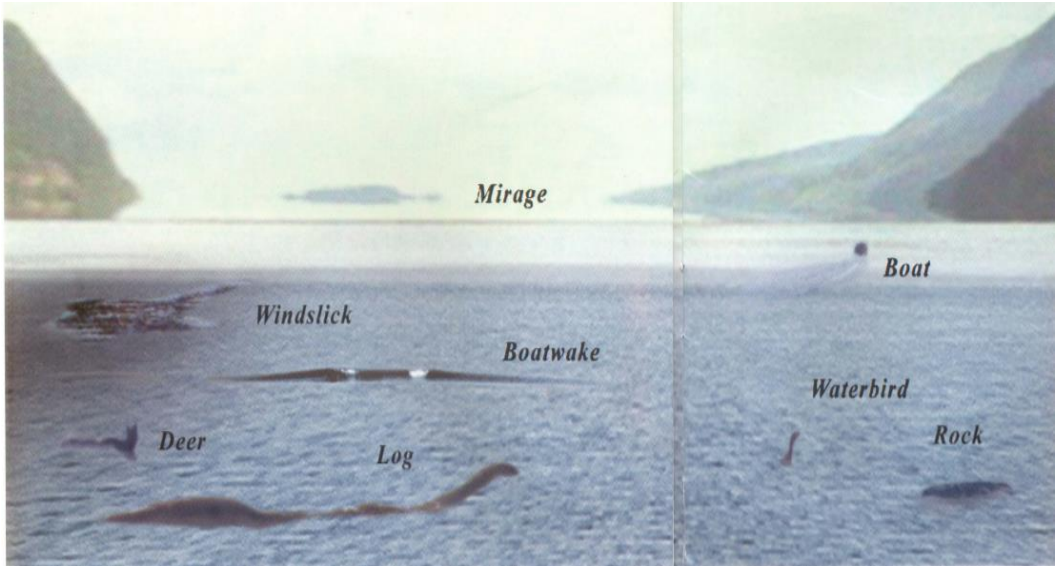

Figure 1 - Pictorial montage of various common objects, animals and phenomena which cause eyewitness misperceptions or misidentifications of Nessie in Loch Ness (Shine, 2006: 12-13).

explain some eyewitness accounts of Nessie and lake cryptids in general (Nickell, 2007) and so do mirages (Lehn, 1979) which are by no means rare at Loch Ness. A mirage is an optical phenomenon in which refracted rays of light produce a displaced image of a distant object;

mirages have been observed at the loch under certain atmospheric conditions (Williams, 2015: 206) and have even tricked a few experienced observers (Gould, 1934: 112; Bauer, 1986: 6-7).

The second category of hypotheses for the Loch Ness Monster are extraordinary or unusual and include surviving plesiosaurs, unknown animal species and known but exotic animals (non-indigenous to Scotland) who must have entered the loch from the North Sea via River Ness[xxii]). There are methods to falsify these ideas; the loch could be fully drained (Law, 2011), or seined with a big net and if no elusive or exotic animals are found this would disprove their existence in the loch (Pasquarello, 1984). Both these methods are environmentally destructive but there's a way to catalogue animals in the loch without causing habitat destruction or biodiversity loss. In 2019, scientists undertook an environmental DNA study by taking water samples from the surface and depths of Loch Ness which produced evidence of 500 million individual organisms and 3000 species as living in the loch (Gilchrist, 2019). The study identified animals including birds, deer, toads, eels, salmon, dogs, even humans. However, 20% of e-DNA samples remain unidentified; Bauer's hypothesis the putative monster is an unknown animal is not falsified by the results (Bauer, 2020: 103). The fact a small portion of the e-DNA has not yet been identified does not necessarily mean there is an unknown species in the loch since the genomic database is incomplete for many different known animal species.[xxiii] In the near-future when more species have been DNA sequenced – this will potentially falsify the Loch Ness Monster as an unknown or elusive animal species. There will never be plesiosaur e-DNA to match samples,[xxiv] but it has been proven beyond a reasonable doubt there is no population of plesiosaurs living in the loch:

> Even if we were to imagine that plesiosaurs had survived undetected somewhere in the oceans, it is unlikely they could have colonised Loch Ness. They were tropical animals, unsuited for the cold waters of the loch… Plesiosaurs would also require more food than the loch can provide. (Loxton and Prothero, 2013: 158-159)

Bauer (2002) rejects the plesiosaur hypothesis, and today favours the giant sea-turtle hypothesis (Bauer, 2020). Coleman (2009) asserts cryptozoologists now reject the plesiosaur hypothesis[xxv] despite at the same time it is said "the most popular and persistent Nessie identity is an evolved, modern-day plesiosaur" (Shuker, 2016: 37). This discrepancy is explained by the fact the most popular image of Nessie in literature still resembles a plesiosaur. Do different unknown animal hypotheses fare any better than the plesiosaur hypothesis? Aside from an elusive giant species of sea-turtle, suggestions include a giant eel (Cohen, 1970: 112),[xxvi] 'long-necked' otter (Burton, 1961: 165-170), seal (Costello, 1975: 321) or giant amphibian (Mackal, 1976: 216).[xxvii] There is no physical evidence for these creatures existing in Loch Ness and there are reasons to doubt their existence. Any animal species requires a minimum viable population (MVP is a group of interbreeding individuals) and a food source to survive. In the 1970s, scientists estimated the MVP of Nessies to be between 10 to 157, depending on its biomass (Sheldon and Kerr, 1972; Scheider and Wallis, 1973; Sagan, 1976). If there are dozens of Nessies, where are the bones? Rines (2001) tried to solve this problem by claiming the population went extinct. However, if Nessies formerly lived in Loch Ness, photographic evidence from the 20th century should be convincing; instead, photos without exception taken since 1934 (Hugh Gray's photo) are either ambiguous, misidentifications, or verified hoaxes (Nickell, 2006: 15-21; Naish, 2013; Binns, 2017: 57-79). Campbell (2002: 96) concludes the "photographic evidence [for Nessie] is poor. Of the twenty-one still photographs, it seems seven are hoaxes, five are of natural phenomena and six provide insufficient data for evaluation". The absence of evidence since the 1930s for the existence of the Loch Ness Monster is arguably now evidence of absence (Garcia, 2020).[xxviii]

Monster Meteorology

If the putative monster in Loch Ness is not an unknown animal species, is there no "mystery waiting to be unlocked"? (Binns, 2019: 218). Reported observations of Nessie are many things, not a single phenomenon. However, not all eyewitness reports can be explained by mundane phenomena and in this sense "there is a real mystery at Loch Ness" (Shine, 2006: 28), which remains unsolved. Although most reports of the Loch Ness Monster are misidentifications of prosaic phenomena, surveys of eyewitness accounts independently estimate 5-10% require an extraordinary or unusual explanation (Burton, 1960; Mackal, 1976: 200-201).[xxix] For example, Bauer (2002: 234) mentions a report corroborated by different observers on opposite sides of the loch; it is quite unlikely these multiple eyewitnesses confused known fauna. Burton (1960: 775, 1961: 157) struggled to explain a small number of sightings reported under 30-yards (90-feet) as misperceptions of mundane floating objects or fauna: "There still remain a number of convincing accounts of a long neck and head seen at close quarters, at distances of about 30 yards". If the unidentified and exotic animal hypotheses are ruled out, what explanation does this leave? Some argue Nessie is a paranormal entity (Redfern, 2016), but this is unreasonable and books from this perspective are "typically crankish in their gullibility" (Bauer, 1986: 96). In 1976, the meteorologist Terence Meaden plausibly suggested a small number of sightings of the putative monster in Loch Ness could stem from misperceptions of rare meteorological phenomena (this would explain a few eyewitness accounts difficult or impossible to explain by prosaic phenomena). Meaden's (1976a) interesting article was published in a scientific journal but has virtually gone unnoticed.[xxx] Williams (2015: 258) describes Meaden's theory as follows:

> Wind can incite water to behave in a monstrous fashion. The mini tornadoes known as dust devils have an aquatic counterpart, which can spring up, move across a stretch of water then collapse. 'Water devils' can appear solid, especially when seaweed or floating debris are dragged up into the rotating column of water, and might explain reports of 'sea serpents' seen like rising like pillars out of the ocean. The editor of the Journal of Meteorology, writing to Peter Scott in 1978 believed that water devils could account for some monster sightings. (Williams, 2015: 258)

Water devils or 'steam devils' (Lyons and Pease, 1972) are an unusual phenomenon, especially in Scotland (they should not be confused with waterspouts[xxxi]). In the 1980s, the water (or steam) devil hypothesis for the Loch Ness Monster was supported by another meteorologist (Rowe, 1987), who compiled reliable reports of miniature whirlwinds over the surface of Loch Ness. Meaden realised water-devils explain not more than a dozen Nessie sightings and encouraged meteorologists to seek different natural weather explanations, on the basis some "observations remain explained" (Meaden, 1976a: 123). Unfortunately, fanciful animal hypotheses continue to preponderate in Nessie literature (Cornes, 2019; Gerhard, 2021) and meteorological theories do not get the attention they deserve.[xxxii] Hitherto, no new meteorological hypothesis has been proposed – the author of this paper suggests reflections of luminous clouds on the loch explain three sightings of Nessie seemingly not explainable by any mundane phenomena. Two of these are listed by Mackal (1976) and include an observation from the closest reported distance (15-yards). The third sighting of interest was made by Tucker (1960). What likely rules out prosaic phenomena for this reported sighting is the fact Denys W. Tucker was an

expert and trained observer in fauna having worked at the Natural History Museum, London and in his own words was a "professional marine biologist of respectable experience" (Williams, 2015: 155). Tucker would not have confused a known animal species with Nessie. Binns (1984) in *The Loch Ness Mystery Solved* mentions Tucker, but not his spectacular sighting presumably because he could not offer an explanation for it. Tucker's sighting is curiously even omitted by Mackal (1976), but it is listed among monster reports compiled by Ulrich Magin; reproduced by Bauer (1986).

Figure 2 - Reflection of noctilucent clouds on Greenwater Lake Provincial Park, Saskatchewan, Canada; photo taken by Jeanine Holowatuik in July 2020.

In the section of his book 'Atmospheric Sources of Deception', Campbell (2002) notes cloud shadows can explain common misperceptions of the Loch Ness Monster. However, reflections or shadows on the loch of tropospheric clouds appear flat. Eyewitnesses instead tend to describe a hump "said to look like an upturned boat" (Bauer, 2002: 234), or multiple undulating humps, above the water. Out of forty-three eyewitness reports recorded by Burton (1961: 37), 39 (91%) describe one or more humps (see Fig. 4).[xxxiii] Shadows or reflections of tropospheric clouds are therefore a poor explanation for Loch Ness Monster sightings and are dismissed by sceptics as a plausible explanation (Nickell, 2006: 14). On the other hand, reflections of noctilucent clouds might explain some sightings of humps above the water surface (see Figs. 2, 3). This is because brightness affects perception of depth cues and brighter objects are perceived to be closer than darker objects. Noctilucent clouds (NLCs) are an extraordinary type of luminous cloud in the mesosphere and are only visible in the summer, during twilight. Luminosity of NLCs is caused by reflection of the sun's light on ice crystals and dust particles high up in atmosphere between morning and evening twilight (i.e., between dawn and sunrise and between sunset and dusk).[xxxiv] Noctilucent clouds in the Northern hemisphere, can only be viewed at latitudes between 50 and 70-degrees (NLC reports are usually between 55 and 65-degrees); Loch Ness is 57-degrees N. Most reported Loch Ness Monster sightings occur when noctilucent clouds are visible in the sky in the Northern Hemisphere between May and August (Gadsden and Parviainen, 2006: 8). As noted by Mackal (1976: 85) based on data for 214 reports of the putative monster, "Do the observations occur during any particular months during the year? Yes, July and August". Willums (1976) based on 258 recorded reports (1962-1971), similarly found most sightings of the Loch Ness Monster (77%) took place from May through August. How many sightings took place during twilight using Mackal's data? For 122 eyewitness reports when

time of day was mentioned – a handful occurred during twilight but only two stand out as explainable by NLCs.

The two eyewitness accounts recorded by Mackal (1976) of interest to the NLC hypothesis:

- An observation of a brown single hump made in August 1961 (day is not mentioned) at 22:30 pm for quite short duration under calm surface conditions of the loch by two fishermen in a boat at 15-yards (45-feet) which remains the closest reported distance for a Nessie sighting. Both eyewitnesses reported seeing a "wide head" above surface of the water, but the head was "not set at right-angles to the neck" (Holiday, 1968: 42). The eyewitnesses described the "wide head" (about 5 feet) as not having eyes, ears nor a nose and reported water disturbances because the monster had submerged/resurfaced.
- An observation made on June 15, 1965, at 22:30 pm of a hump in the loch resembling an overturned boat for long duration (at least an hour) under calm surface conditions by two eyewitnesses; one a police sergeant. On opposite side of the loch, an independent eyewitness corroborated the sighting (Bauer, 2002: 234). The latter eyewitness named Frederick Holiday followed the moving hump in the water along the bank of the loch. All three eyewitnesses claimed to have observed the Loch Ness Monster from a long distance (one to two miles), but Holiday used binoculars giving him a much better view.

Figure 3 - Reflections of noctilucent clouds over Blyth pier, Northumberland, England; photo taken by Owen Humphreys in June 2019 (Simons, 2019)

The latter eyewitness account described by Holiday (1968) strongly suggests reflections on the loch of noctilucent clouds were observed.[xxxv] Holiday describes an "illumination" over the loch (Holiday, 1968: 103), mentions the monster was "yellowish-brown" in colour and was drifting but "gave no indication of being alive, the thing had a sort of latent strangeness about it" (Holiday, 1968: 104). Holiday (1968: 105) clarifies "there was no sign of a head, neck or tail – simply this large, mustard coloured mass". Noctilucent clouds are typically white or bluish white, but can be reddish (Avaste et al. 1988), brownish and yellowish, even orange (Ludlam,

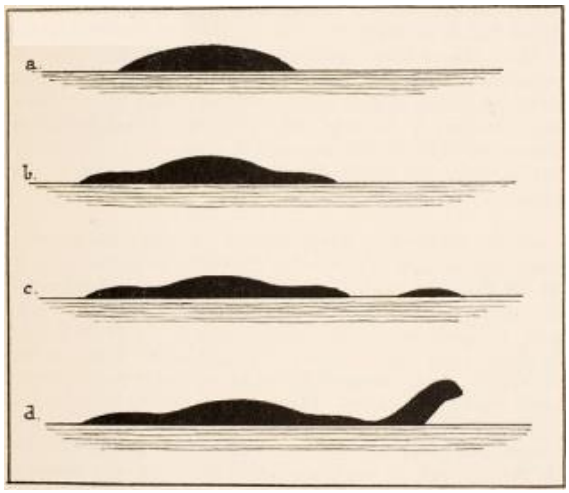

Figure 4 - The shape of monster humps (Gould, 1934).

Figure 5 - Noctilucent clouds (in the shape of undulating humps) over Paris, France; photo taken by Bertrand Kulik on 5th July 2020 at 11:10 pm.

Figure 6 - Noctilucent clouds in wave-like (so-called fluctus) shape over Rabka-Zdrój, Poland; photo taken by Radoslaw Ziomber in July 2017.

1957: 343). Willums (1976) calculated from 258 reported sightings of Nessie, ~10% (25) are "brown or other [non-black] colours", while Burton (1961: 40) from 30 early reports of humps

calculated 13% (4) were non-black. This means some eyewitness descriptions of the Loch Ness Monster fall within the colour spectrum of noctilucent clouds. The shapes of NLCs are diverse (Ludlam, 1957: 341-342) and can appear as undulating humps or waves (Dalin et al. 2010, see Figs. 5, 6). NLCs like all clouds are in motion.[xxxvi] This can easily explain Holiday's description of a drifting (non-stationary) monster hump. The other report (August 1961) is less probable to have been an NLC when compared to Holiday's observation, but there is a good chance what the fishermen observed was an NLC reflection (which was an unfamiliar phenomenon to them). Both the anglers described the brown head of the monster as having no eyes, ears nor a nose which discards the possibility of a known animal; the "head" they supposedly observed was possibly a reflection considering its size (5-feet). Most books and articles on Nessie have little to say about this peculiar sighting; it is very difficult to explain and is often not mentioned.

The third monster sighting of interest to the NLC hypothesis occurred on March 22, 1959, by Denys W. Tucker. He described his sighting as follows in an article published in *New Scientist*:

> I, a professional marine zoologist of respectable experience, did see a large hump travelling across flat calm water between Inchnacardoch and Glendoe on 22 March 1959, and so quite unashamedly assert that it belonged to an unknown animal. (Tucker, 1959)

Tucker later clarified the hump was surrounded by a foam or shiny substance:

> Off Inchnacardoch on the evening of 22 March 1959 I saw a triangle of foaming water following a hump towards the far shore, where it either sank or melted into the twilight under the opposite bank. Boat it certainly was not, but I plodded around by Fort August checking that there was nothing else on the water nor any boat drawn up on the beach. (Tucker, 1989: 211)

Costello (1975: 90) in his book *In Search of Lake Monsters*, mentions the same sighting:

> On March 22, 1959, Tucker himself saw a large hump travelling across flat calm water between Inschnacardoch and Glendoe, achieving something Gould, Burton and Whyte never did. He is convinced it was an unknown animal.

Tucker's sighting did not occur during May through August when noctilucent clouds are visible in the Northern Hemisphere so his observation cannot be explained by a reflection of a natural luminous cloud phenomenon on the loch. Gadsden and Parviainen (2006: 27), however, point out that luminous clouds can be created artificially by rockets – exhaust particles can diffract sunlight into iridescent colours; a photo taken in 1988 of a cloud-trail from a launched rocket shows iridescence and reflection on a lake (see Fig. 7). In 1957 the RAF built a missile test site in the Outer Hebrides; rockets were launched the same year as Tucker's sighting. Could Tucker have seen a reflection on Loch Ness of a cloud-trail from a rocket? Was the "foam" the reflected iridescence? Tucker was certain he did not misidentify a boat or known animal and his strange observation at Loch Ness matched "nothing in his encyclopaedic knowledge of freshwater fish and their predators" (Williams, 2015: 113). This leaves Tucker's sighting an unsolved mystery.

Figure 7 - Artificial cloud-trail and iridescent reflection on a lake; photo taken in July 1988 (Gadsden and Parviainen, 2006).

Conclusion

As long as some eyewitness accounts of the Loch Ness Monster remain difficult or impossible to explain by mundane or prosaic phenomena, "new ideas will be introduced which will explain away a few percent of the past observations" (Meaden, 1976a: 123). A small number of Nessie sightings can plausibly be explained by reflections on the loch of noctilucent clouds. The author of this paper calls on cryptozoologists or investigators of the Loch Ness Monster who continue to believe Nessie is an exotic (Cornes, 2019) or unknown animal (Bauer, 2020; Gerhard, 2021), to abandon their hypotheses for extraordinary meteorological explanations (such as NLCS) to explain the few eyewitness accounts of Nessie which are unexplainable by prosaic phenomena.

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i From January to October 2022, only six monster sightings were reported (The Official Loch Ness Monster Sightings Register) http://www.lochnesssightings.com/ [accessed 07/01/2023].

ii It is sometimes claimed there are eyewitness accounts of the Loch Ness Monster in literature dating back centuries; however, Binns (1984: 50-58) proves these are mistaken locations (i.e., in separate lochs) or the literary sources are spurious, e.g., Keel (1970: 268) incorrectly claimed a newspaper in 1896 refers to a monster in Loch Ness, despite the actual article was published in 1897 and does not mention a loch (Watson, 2016). Prior to the 1930s, there were recorded traditions of water-horses or kelpies at Loch Ness (Stewart, 1860: 121; Mackinlay, 1893; 173-174) but these have no relation to Nessie, contrary to dubious attempts to link them (Dinsdale, 1973; 19-24; Costello, 1975: 164-165; Watson, 2011); see Binns (2017: 159-173) for rebuttal.

iii Thomas (1988) rationalises the "water beast" as a seal or walrus.

iv Nearly all these reports are second or third hand (Bauer, 1986: 35-36). For this reason, they are at best hearsay; Gould (1934: 30) dismissed these reports as rumors, "of no great value".

v In August 1930, the *Northern Chronicle* published an article on three fishermen who heard a noise in the loch they presumed was an unknown animal, but they did not observe it (Loxton and Prothero, 2013: 126-127). This early recorded oral report was not an eyewitness testimony.
vi As noted by Nickell (2006: 14), the tracks were proven to be made from a hippo's hoof cast.
vii It has oddly been claimed the photo contains the face of a child (Akins, 1977: 77), yet another interpretation is of a "Labrador dog swimming… with a stick in its mouth" (Campbell, 2002: 26). Burton (1961: 80) in contrast thought the photo is of mere driftwood. Binns (2017: 61-62), instead maintains the photo is a hoax of "a small model photographed at close quarters". These (and other) interpretations including Naish's, have been recently disputed by Watson (2022).
viii The expedition was organised by Edward Mountain who paid 20 men to patrol the stretch of the loch; 23 miles with cameras and binoculars for a month (Mountain, 1934; Binns, 1984: 37).
ix Namely how Nessie found its way into the loch to begin with; the loch was frozen during the last Ice Age which ended approximately 10,000 years ago. Bauer (1986: 162) credits Whyte as the first "to contemplating the existence of a breeding population landlocked after the last ice age" and Witchell (1989: 87) describes Whyte's book as a step towards "serious investigation".
x Gould in his defense could though argue the loch contained only one monster because it was trapped, having entered from the River Ness (with its breeding ground somewhere in the North Sea). A 1970 tourist pamphlet on Nessie discusses whether it was a native species or a visitor from the North Sea via the River Ness (Carruth, 1970: 8-9).
xi A separate loch, about seventy miles from Loch Ness. There have been a few dozen reports of large mysterious creatures in Loch Morar and its putative monster is named 'Morag'.
xii In his book *Searching for Hidden Animals*, Mackal concluded: "To this day the real identity of the Loch Ness animals remains a mystery" (Mackal, 1980: 236). Mackal's final publication on Nessie (a conference paper) was published in *The Scottish Naturalist* (Mackal, 1988).
xiii Campbell (2002: 98) notes "it has not yet been established Loch Ness was ever open to the sea". Shine in 1983 conducted a core sampling program to test whether the sea entered Loch Ness post-glacially, but the results showed no evidence of marine life in sediments of the loch.
xiv Official Loch Ness Monster Sightings Register (2009).
xv Some recent notable books include *The Man Who Filmed Nessie* by Angus Dinsdale (2013), *A Monstrous Commotion* by Gareth Williams (2016) and *Decline and Fall of the Loch Ness Monster* by Ronald Binns (2019).
xvi Many believers in Nessie as an elusive animal species have conceded to sceptics most reports are malobservations of mundane phenomena; for example, Clem Skelton the field director of LNIB estimated 80% to 90% of eyewitnesses, "who think they have seen the monster have really seen something else" (Cohen, 1970: 96). Witchell (1989: 57) estimated 80% to 85%.
xvii Mackal (1976) in his book appendix recorded distances for 144 sightings; 17 of these (12%) were from 50-yards (150-feet) or less; only one of these was from close as 15-yards (45-feet).
xviii As noted by Loxton and Prothero (2013: 164), "Psychologists emphasize that the plasticity of memory is a defining factor of all first-hand testimony". Eyewitnesses tend to recall details more accurately and provide vivid mental images shortly after an observation than over longer periods of time because of lapses in memory or forgetfulness. Memories are prone to distortion and embellishment by post-event information which is known as the 'misinformation effect'.
xix Mackal (1976: 202) has argued Nessie hoaxers are rarely malicious but practical jokers.
xx One of the very few zoologists who claimed to have seen the putative monster when visiting Loch Ness was Denys W. Tucker who favored the plesiosaur hypothesis (Tucker, 1960).
xxi Shine (2006: 12) mentions "Wind slicks, boats, seals, water birds and floating logs". Wind slicks are calmer patches of water, "dark from the shore, making it seem as though something

is under the water" (Shine, 2017). For a near complete list, see Paxton and Shine (2016). Seals are known to visit Loch Ness from Moray Firth via River Ness, albeit infrequently, "once every two years" (Williamson, 1988) and they could explain some monster sightings (Binns, 2017: 82). Burton's (1961: 170) idiosyncratic theory gas-propelled rotting vegetation is the source of many Nessie sightings is doubtful (Holiday, 1968:49); Shine (1993) notes research "has shown little gas production in deep Loch Ness sediments" but a geologist has argued seismic activity beneath the loch (releasing methane gas) causes disturbances on the surface (Piccardi, 2001).

[xxii] Shine (1988, 2006: 27-28) entertains the possibility a few historical sightings of Nessie could have been a sturgeon. He notes that one was caught by the canal entrance at Loch Ness in 1871. Paxton and Shine (2016) include a list of exotic species hypotheses or "animals outside their known ranges in space". Sharks have been suggested to explain Nessie sightings, but the main difficulty with this explanation is most sharks cannot swim between salt and freshwater. Eccentric suggestions e.g., elephants (Jordan, 2006) and sea lions (Cornes, 2019) are based on the idea these exotic animals had escaped from traveling circuses or zoos and entered the loch.

[xxiii] Another e-DNA failed to identify 48% of samples from a New York subway largely because "our genetic libraries are still incomplete" (Zhang, 2015); see also Watson (2019a, 2019b).

[xxiv] The oldest DNA, technology can sequence is about one million years old, yet Plesiosaurs went extinct ~65 million years ago based on palaeontological evidence (Naish, 2017: 105).

[xxv] Notable proponents of the plesiosaur hypothesis in the late 20th century abandoned the theory or became sceptical e.g., Denys Tucker: "I might give my plesiosaur hypothesis a rating of 20 percent, thus admitting how far it falls at present" (Tucker, 1989: 227).

[xxvi] The giant eel hypothesis was proposed as early as the 1930s (Gould, 1930: 128-129). There has been a renewed interest with the discovery of eel e-DNA, "at pretty much every location sampled in Loch Ness" (Gilchrist, 2019). A sceptical study of enormous sized eels in the loch has recently been published as a preprint (Foxon, 2023).

[xxvii] A list of unknown or elusive animal hypotheses for Nessie can be found in Paxton and Shine (2016) under the sections "novel animals" and include giant eels, crabs, and long-necked seals.

[xxviii] Sometimes it is said a negative claim cannot be proven, but this depends precisely on the threshold of proof (Hales, 2005; Law, 2011). It has been proven beyond a reasonable doubt (say with 99% probability) the putative monster in Loch Ness as an unidentified animal does not exist. This does not though mean beyond all doubt meaning with absolute certainty (100%).

[xxix] Mackal (1976: 200) wrote "90% can be identified as errors, mistakes, misinterpretations" and the appendix of his book lists 251 out of 3000 (8%) as not "waves, birds, logs, and other such known objects". A more detailed analysis by a LNIB member taking into consideration duration of observations, weather and surface conditions of the loch, distance of observers, plus reliability of eyewitnesses, reduces this list to barely 100 sightings (Akins, 1977: 43). In other words, the number of eyewitness reports of Nessie difficult or impossible to explain by prosaic phenomena is lower than what Mackal estimated. It remains unclear where Mackal got access to 3000 reports; as of August 2021, The Official Loch Ness Monster Sightings Register records only 1136 observations and in the 1980s, 400 to 600 reports were estimated (Binns, 1984: 177; Bauer, 1986: 10). Perhaps this discrepancy can be explained by the fact many of the eyewitness reports Mackal studied were second or third hand rather than first-hand eyewitness testimonies.

[xxx] Scott (1976b) was one of the few researchers to take an interest in the water devil hypothesis and agreed with Meaden "it may well be the explanation of a number of Loch Ness sightings".

[xxxi] Waterspouts stretch between the base of a cumulus or cumulonimbus cloud and water; water-devils in contrast tend to be much smaller whirlwinds over water, often under 100 meters above surface, although there are rare reports of water-devils reaching into low-lying cumulus clouds.

[xxxii] The few publications on monster meteorology include Meaden (1976a, 1976b), Rowe (1987) and Botley (1934, 1980). Botley's (1934) article is aptly titled "Meteorology and Monsters".

[xxxiii] A long neck and head are mentioned less frequent in recorded monster sightings, under 25% (Burton, 1961: 119). Prosaic explanations include diving birds (with only head/neck showing), floating branches or swimming deer (Campbell, 2002: 22-23). One underwater photo purported to be of a long-necked creature is "indistinct that only by a great leap of faith could one make an animal out of it" (Ellis, 1995: 29). Another underwater photo, known as the "gargoyle head" is most likely an inanimate object. It has been claimed the object in this photo is a carving from a Viking longboat (Halstead et al. 1976) although this idea has been criticised (Scott, 1976a). While the longboat idea has been defended (Halstead, 1982: 198) no archaeological evidence has substantiated it. Naish (2017: 100) has pointed out that if the photo is rotated, "it looks like a few lumps of rotten wood". A tree stump was found in the same place (Campbell, 2002: 61).

[xxxiv] Noctilucent clouds are the highest type of cloud and form in the mesosphere from 80 to 85 km (50 miles), in the coldest part of the atmosphere. NLCs can be observed by the naked eye during nautical twilight and most of astronomical twilight meaning when the sun is between 6 and 16 degrees below the horizon, when the sky is dark enough to see luminosity but not night. NLCs are seldom observed during civil twilight because they would be too faint to see without a telescope, although there could be exceptions under rare conditions. Noctilucent clouds are composed of ice particles and dust (probably left by micro-meteors); they can reflect rays of sunlight when the sun is below the horizon during twilight because of their high altitude in sky.

[xxxv] The failure by Holiday (1968) to recognise a meteorological phenomenon for his sighting left him proposing an unknown animal species. He later abandoned his original hypothesis but unwisely "sought to connect Nessie with psychic phenomena and UFOs" (Bauer, 1986: 97).

[xxxvi] The velocities of NLCs vary depending on atmospheric conditions, Ludlam (1957: 345-346) documents speeds of motion up to 100-200 meter per second but the lowest range is 13 m/s.

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