Review of the African distribution of the brine shrimp genus *Artemia*

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Abstract

Brine shrimp (genus *Artemia*) are small (8 to 12 mm long) cosmopolitan crustaceans (Anostraca) found predominately in hypersaline water bodies such as inland salt lakes and pans, coastal lagoons, and salt works at salinity levels above 40 g·ℓ⁻¹. They have been extensively studied due to their high monetary value as food for larval fish in aquaculture and their unique reproductive strategies. Brine shrimp occur as either bisexual species or as parthenogenetic populations. Despite published reviews of their world-wide distribution little is known about their occurrence in Africa. This review adds new information about 70 African *Artemia* sites and lists 26 potential sites and their coordinates. Sixteen sites in Southern Africa and Namibia were visited during a collecting trip, and new information on the reproductive mode of nine of these sites is given. Several South African populations exhibit bisexual reproduction. In Namibia there are two parthenogenetic populations (Walvis Bay and Swartkops) and an additional bisexual population (Hentie’s Bay). A mixed population (bisexual and parthenogenetic reproduction at the same site) was found at Coega, South Africa.

Keywords: Biogeography, brine shrimp, site description, hypersaline water bodies

Introduction

Brine shrimp of the genus *Artemia* (Crustacea, Anostraca) are of interest to both biologists studying their evolution and developmental biology (Abatzopoulos et al., 2002) and aquaculturists using them as live food in fish and shrimp larviculture (Dhont and Sorgeloos, 2002). The life cycle of *Artemia* can begin as an embryo within a dormant cyst. Depending on environmental conditions, embryos can enter into diapause and arrested development for many years and are capable of surviving a very wide range of environmental conditions (Clegg and Trotman, 2002). *Artemia* nauplii can be easily hatched from cysts and have various applications in aquaculture, for example: they can be enriched with nutrients, i.e., essential fatty acids and vitamins to improve their nutritional value to cultured fish larvae or juveniles (Dhont and Sorgeloos, 2002); they have been used as carriers of spawning hormones to treat fish diseases or induce spawning in adult fish (Burton et al., 1998); and they have been tested as a promising vehicle for probiotics in marine fish larviculture (King, 2002).

The genus is cosmopolitan and comprises both sexually reproducing species and parthenogenetic populations. Salinity is the most important environmental factor governing *Artemia* distribution with populations being found in salt lakes and pans at salinity levels above approximately 40 g·ℓ⁻¹ (Vanhaecke et al., 1987) where fish and many predatory invertebrates are absent (Browne and MacDonald, 1982). Information from reviews (Persoone and Sorgeloos, 1980; Browne and MacDonald, 1982; Vanhaecke et al., 1987 and Trianta-
Methods

The sampling trip through parts of South Africa and Namibia was conducted in July/August 2003. Salt pans were visited and GIS coordinates were recorded. Either live *Artemia* or *Artemia* cysts were collected. Adult *Artemia* were preserved in alcohol (>95% ethanol) and kept frozen at -20°C. Cysts were cleaned and dried and kept at -20°C and used for genetic analyses. The approximate size of the pans and the water depth (m) at the time of sampling were estimated, and the salinity (g·ℓ⁻¹) was recorded using an Atago Hand Refractometer (Model S-10E). Annual average temperature records were taken from information available in GIS databases pertaining to the respective coordinates. Adult *Artemia* were sexed by using a dissection microscope to discern the egg sacs of females or the claspers of males.

Results and discussion

*Artemia* populations in Africa

Most African *Artemia* populations have been recorded from countries bordering the Mediterranean (Table 1). Although the

| Country     | Locality                          | Geographical coordinates | Reproductive mode/species | Artemia research centre number | Reference number |
|-------------|-----------------------------------|--------------------------|---------------------------|--------------------------------|-----------------|
| Algeria     | # ?                               |                          |                           | 1285*, 1182*, 1127*, 1098*, 1066*, 1065* | 2                |
|             | Chegga Oase                        | 34°29'N-05°53'E          |                           |                                | 1                |
|             | Chott Meden                        | 34°01'N-06°20'E          |                           |                                | 1                |
|             | Chott Ouargla                      | 31°57'N-05°20'E          |                           |                                | 3                |
|             | Dayet Morselli                     | 35°30'N-00°46'E          |                           |                                | 14, 15           |
|             | # El-Menaceria                    |                          |                           |                                | 15               |
|             | Gharabas Lake                      | 35°35'N-00°25'W          |                           |                                | 2                |
|             | # Mellaha Guergour El-Amri        | 35°50'N-05°15'E          |                           |                                | 1                |
|             | Salin de Bethiona                  |                          |                           |                                | 1129*            |
|             | Sebkat Idemdi                      | 35°43'N-06°32'E          |                           |                                | 3                |
|             | Sebket Ez Zemouk                   | 35°53'N-06°33'E          |                           |                                | 1                |
|             | Sebket Oran                        | 35°32'N-00°48'W          |                           |                                | 1                |
|             | # Sekha Azrew                      | 35°43'N-00°08'E          |                           |                                | 3                |
|             | # Sekba d’Arzeut                   |                          |                           |                                | 1119             |
|             | # Sekba N’zourit                    | 35°50'N-06°35'E          |                           |                                | 3                |
|             | # Sekba Sidi Bouzian                | 35°52'N-00°35'E          |                           |                                | 3                |
|             | Tougoud                            |                          |                           |                                | 15               |
|             | # Santa Maria                      |                          |                           |                                | 30               |
| Egypt       | # Bourg El-Arab                    | P                        | 1497*, 1146*, 1136*, 1131*, 1063 | 4, 15, 17, 18, 31 |
|             | El Max Saline (Alexandria)         | P                        | 1142*, 1132*, 1155*, 1064* | 4, 15, 17, 18, 31 |
|             | Ismailia                           | 30°36'N-23°15'E          |                           |                                | 1                |
|             | Port Fouad                         | P                        | 4                         |                                | 2                |
|             | Port Said                          | P                        | 1152, 1144*, 1140*, 1134*, 1135*, 1114 | 4, 15, 17, 18, 31 |
|             | Qarun Lake                         | P                        | 1139*, 1135*, 1118*       |                                | 2                |
|             | # Rassoua                          | 1145*, 1143*, 1141*, 1138 |                           |                                | 2                |
|             | Solar Lake (Sina)                  | 29°10'N-34°50'E          |                           |                                | 4, 15, 17, 18, 31 |
|             | Wadi Natron                        | 30°10'N-30°27'E          | A. salina                 |                                | 6                |
|             | # Wadi el Natrun                   | A. salina (B *)          | 1290*, 1147, 1117, 1026*, 5, 56, 358 | 2, 4, 6, 31 |
| Kenya       | Elmenteita                         | 00°27'S-36°15'E          |                           |                                | 1                |
|             | # Fundisha                         | 1035*                    |                           |                                | 2                |
|             | # Fundisha                         | A. salina                |                           |                                | 5                |
|             | # Kensait Saltworks                | 1036*                    |                           |                                | 2                |
|             | # Kensait Saltworks                | A. franciscana           |                           |                                | 2                |
|             | # Kurawa Saltworks                 | 1441*                    |                           |                                | 2                |
|             | # Kurawa Saltworks                 | A. salina                |                           |                                | 5                |
|             | # Malindi Saltworks                | 1440*                    |                           |                                | 2                |
|             | # ?                                | 339, 1437*               |                           |                                | 2                |
|             | # Abu-Khammash                      | A. salina                |                           |                                | 2                |
|             | Gabr Acun (Fezzan)                 | 25°22'N-13°E             |                           |                                | 6                |
|             | Mandara                            | 26°40'N-13°20'E          |                           |                                | 16, 19, 21      |
|             | Mandara                            | B                        | 341, 1459                 |                                | 16, 19           |
|             | Quem el Ma                         | 26°41'N-13°22'E          |                           |                                | 16, 19           |
|             | Kamba-Az-Zallaf (Fezzan)           | 27°26'N-13°E             |                           |                                | 20               |
|             | Trouna                             | 26°50'N-13°30'E          |                           |                                | 19               |
|             | # Trouna                           | 340                      |                           |                                | 2                |
|             | # Ankembe Saltworks                | P                        | 1314*                     |                                | 2, 4, 7          |
|             | # Hany Saltworks                   | A. franciscana           |                           |                                | 4                |
|             | Salins de Diego Suarez             | 12°19'S-49°17'E          |                           |                                | 1                |
| Morrocco    | # Chemmnaa                         | A. salina                |                           |                                | 6                |
|             | Larache                            | 35°12'N-02°20'W          |                           |                                | 8, 22            |
|             | Moulaya Estuary                    | 35°07'N-02°20'W          |                           |                                | 1                |
|             | Qued Ammatafma                     | 28°18'N-12°00'W          |                           |                                | 16               |
|             | Qued Chbheica                      | 28°25'N-11°50'W          |                           |                                | 16               |
|             | Sebkett Bon Areg                   | 35°10'N-02°50'W          |                           |                                | 1                |
|             | Sebkett Zima                       | 35°05'N-08°40'W          |                           |                                | 1                |
|             | # Souzamma                         | 1427*                    |                           |                                | 2                |
| Country          | Area                     | Coordinates                    | Artemia Population |
|------------------|--------------------------|--------------------------------|--------------------|
| Namibia          | Henties Bay Salt Refineries | 22°00'S-00°14'E               | *1418*             |
|                  | Swakopmund Saltworks     | 22°40'S-14°34'E               |                    |
|                  | Vineta Swakopmund        | 22°40'S-14°34'E               | P, *1186*, 480*,    |
|                  | Walvis Bay               | 22°56'S-14°30'E               |                    |
| Niger            | Teguidda In Tassoun       | 17°26'N-06°39'E               |                    |
| Senegal          | Dakar                    | 14°34'N-17°29'W               |                    |
|                  | Lake Kayar               | 15°55'N-17°11'W               |                    |
|                  | Lake Relba               | 14°50'N-17°20'W               |                    |
| South Africa     | Bloemfontein Saltworks   | P                              |                    |
|                  | Brandvlei Saltworks      | 30°22°S-20°13'E               |                    |
|                  | Coega Salt Flats         | 33°46'S-25°40'E               |                    |
|                  | Driehoekspan             | 29°43°S-23°14'E               |                    |
|                  | Haagegestad Pan          |                                  |                    |
|                  | Hayfield Saltpan         | 29°15°S-24°13'E               |                    |
|                  | Holpan Saltworks         | 30°22°S-20°30'E               |                    |
|                  | Hoop Saltworks           | 30°12°S-20°40'E               |                    |
|                  | Jonkerwater Saltworks    | 30°05°S-22°36'E               |                    |
|                  | Kaalpan Saltworks        | 30°00°S-20°03'E               |                    |
|                  | Klein Soupan             | 30°21°S-22°24'E               |                    |
|                  | Klipfontein Saltworks    | 33°55°S-18°13'E               |                    |
|                  | Kliphoek Salina          |                                  |                    |
|                  | Missionvale Salina       | 33°52°S-25°32'E               |                    |
|                  | Patenoster Salt Pan      | 33°47°S-17°55'E               |                    |
|                  | Playas                   | 1169                           |                    |
|                  | Rietfontein se Pan       | 30°16°S-20°07'E               |                    |
|                  | Reynekespan Saltworks    | 33°44°S-25°47'E               |                    |
|                  | Keynekespan Salt (populations) | 29°43°S-12°15'E          |                    |
|                  | Saldanha Steel           | 33°00°S-18°02'E               |                    |
|                  | Salt Lake                | 29°17°S-24°00'E               |                    |
|                  | Hopetown Salt Pan        | 29°16°S-24°10'E               |                    |
|                  | Kliquefominita Salina    | 33°51°S-25°34'E               |                    |
|                  | Swartkops                | 33°52°S-25°36'E               |                    |
|                  | Swartkops Marina         |                                  |                    |
|                  | Swartkops Cerebosa       | 33°47°S-25°32'E               |                    |
|                  | Soutpan                 | 29°36°S-24°26'E               |                    |
|                  | Velddrif                 | 29°38°S-25°32'E               |                    |
|                  | Velddrif Saltworks       | 33°43°S-18°12'E               |                    |
|                  | Velddrif Saltworks       | 32°47°S-18°10'E               |                    |
|                  | Vermeulepsan             | 29°30°S-24°20'E               |                    |
|                  | Wintersdam Farm          | 25°45°S-26°08'E               |                    |
|                  | Witkraal Saltpan         | 28°58°S-25°31'E               |                    |
|                  | Wilpan Saltworks         | 29°53°S-24°03'E               |                    |
|                  | Yezerfontein Saltworks   | 33°19°S-18°10'E               |                    |
|                  | Zoutaar Saltworks        | 30°19°S-23°05'E               |                    |
| Tunisia          | Bekalta                  | 36°48°N-10°20'E               | *1289*             |
|                  | A. salina                |                                  |                    |
|                  | Chott Ariana             | 36°54°N-10°18'E               | *A. salina*, 636*   |
|                  | Chott Ariana             | 36°54°N-10°18'E               | A. salina*         |
|                  | Chott El Djeral          | 33°42°N-08°25'E               | A. salina*         |
|                  | A. salina                |                                  |                    |
|                  | Ebege                   | 36°47°N-10°14'E               | *A. salina*        |
|                  | Megeine                  |                                  |                    |
|                  | Sebeket Koweza           | 36°26°N-09°46'E               | *A. salina*        |
|                  | Sebeket Mafa Moknine     | 35°39°N-10°53'E               | *A. salina*        |
|                  | Sebeket Sidi El Hani     | 35°31°N-10°27'E               | *A. salina*        |
|                  | Slax                    | 35°43°N-10°43'E               | *A. salina*        |
|                  | Slax                    | 35°43°N-10°43'E               | A. salina*         |

Legend: (B) = bisexual but species not known; (P) = parthenogenetically reproducing population; *= cysts are available at the Artemia Reference Center (ARC), Ghent, Belgium; # = a new Artemia population added to the list since the last general review by Triantaphyllidis et al. (1998). The number in the last column indicates the reference in which the Artemia population was first reported; ? = Site name not known or not given.

References for Table 1

1. Vanhaecke et al. (1987); 2. ARC table; 3. Zemmouri (1991); 4. Triantaphyllidis et al. (1998); 5. Rasowo and Radull (1986); 6. Triantaphyllidis et al. (1997a); 7. Triantaphyllidis et al. (1996); 8. Hontoria and Amat (1992); 9. Triantaphyllidis et al. (1997b); 10. Williams and Mitchell (1992); 11. Seaman et al. (1991); 12. Mitchell and Seaman (1988); 13. Amat et al. (1995); 14. Cole and Brown (1967) cited in Vanhaecke et al. (1987); 15. McCarragher (1972) cited in Vanhaecke et al. (1987); 16. Dumont (1979) cited in Vanhaecke et al. (1987); 17. Por (1968) cited in Vanhaecke et al. (1987); 18. Por (1969) cited in Vanhaecke et al. (1987); 19. Monod (1969) cited in Vanhaecke et al. (1987); 20. Ghannudi and Tufail (1978) cited in Vanhaecke et al. (1987); 21. George and Bobrie (1985) cited in Vanhaecke et al. (1987); 22. De Pinto Canelas (1971) cited in Vanhaecke et al. (1987); 23. De Pinto Canelas (1971) cited in Vanhaecke et al. (1987); 24. Van Baarlen et al. (1987) cited in Vanhaecke et al. (1987); 25. Clark and Bowen (1976) cited in Vanhaecke et al. (1987); 26. Sousa (1994) cited in Triantaphyllidis et al. (1998); 27. Du Toit (2001), 28. Present study – cyst/nauplii samples collected.; 29. Present study – personal communication; 30. Van Stappen (2002); 31. Baxevanis et al. 2004. 32. Toumi et al. (2005).
The reproductive mode for most *Artemia* populations in Algeria has not been established. Populations with a confirmed reproductive mode are bisexual, but their species status is either not known or has not been published. One bisexual population was recorded at a salt works and others were found in natural salt lakes (Zemmouri, 1991). In Libya one population was confirmed as bisexual (Triantaphyllidis et al., 1997b), but the reproductive mode of the other populations was not given. Records from Morocco show one population of *A. salina* (Triantaphyllidis et al., 1997b), one occurrence of a parthenogenetic population, and populations of unknown reproductive mode. Most Egyptian *Artemia* populations are parthenogenetic. *A. salina* was found at the Wadi Natron site in northern Egypt, and a permanent population of *A. franciscana* was discovered at a salt works (Triantaphyllidis et al., 1998). All Tunisian populations have been reported as *A. salina*. Dumont (1979) reported an *Artemia* population from Lake Retba, Senegal. Only personal communications account for the records of all other *Artemia* populations in Niger and Senegal (Table 1), and their reproductive mode is not known.

Records available prior to our sampling trip show the existence of both bisexual species and parthenogenetic populations in sub-Saharan Africa (Table 1). These populations were located at salt works, some of which were operating at the time of sampling, others had been abandoned. In addition, a number of personal communications report the existence of *Artemia* populations which required further investigation. For example, for three of six South African populations listed by Van Stappen (2002) the information is based on personal communications, and their species status is undetermined. *Artemia salina* is reported to have been inoculated into Kenyan salt works (Rasowo and Radull, 1986; see Table 1), but the *Artemia* Reference Centre in Ghent, Belgium, identified *Artemia* from those salt works as *A. franciscana*. Both Mozambique and Namibia have parthenogenetic *Artemia* populations occurring at salt works. A parthenogenetic population as well as *A. franciscana* have been found in Madagascar, with an unidentified population occurring in the northern part of the island. The *A. franciscana* population was not permanent, and had to be inoculated annually (Triantaphyllidis et al., 1998).

The low number of recorded *Artemia* populations in Africa does not reflect *Artemia* distribution on the continent. Large areas of Africa, (i.e., Mauritania, Somalia, Ethiopia, Sudan, and southern Africa) are considered potential *Artemia* habitat (Vanhaecke et al., 1987). However, very few collections have been reported for these areas. Vanhaecke et al. (1987) suggested that 97% of the known *Artemia* populations in Africa are in areas where yearly evaporation exceeds yearly precipitation. Williams (1996) estimated that 37% (11.3 x10³ km⁻²) of the African continent can be categorised as arid and semi-arid where salt lakes are likely to occur.

Salt lakes of northern Africa were among the first on the continent to be investigated, followed by locations in East Africa (Hammer, 1986; Seaman et al., 1991). More recently, the salt pans of Southern Africa have come under investigation (Seaman et al., 1991). Studies of these saltwater bodies have mainly focused on geological and chemical characteristics, with few biological surveys. Thus, the presence or absence of *Artemia* in most of these water bodies remains unclear. Saline water bodies in East and Southern Africa with salinities greater than 40 g·ℓ⁻¹ (Table 3) may contain populations of *Artemia* and should be the focus of further investigations. Lists of salt pans or lakes with salinities below 40 g·ℓ⁻¹ can be found in Seaman et al. (1991), Hammer (1986), Shumway (1999) and Williams (1996).

### Addition of new *Artemia* sites in sub-Saharan Africa

During July and August 2003, adult *Artemia* and cysts were collected from nine and five sites, respectively. For most adult specimens gender could be determined, but as the sample sizes

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**Table 1**

| Site name         | Type | Elevation (m) | Approximate size (km²) | Temperature in °C (average; min/max) |
|-------------------|------|---------------|------------------------|------------------------------------|
| Brandtvlei        | I    | 940           | 4                      | 20.2; -8 / +42                     |
| Coega Cerebos     | C    | 1             | 10                     | 19.1; 0 / +32                      |
| Henties Bay       | C    | 0             | 5                      | 20; 0 / +34                        |
| Kleinzee Yacht Club | N   | 0             | 3                      | 7; 0 / +40                         |
| Klipfontein Salt  | C    | 15            | 5                      | 23.6; 0 / +40                      |
| Missionvale Salt  | C    | 4             | 5                      | 18.3; 0 / +35                      |
| Reynekepan        | I    | 1149          | 0.5                    | 22.2; -6 / +40                     |
| Saldanha Steel    | S    | 40            | 0.5                    | 23.6; 0 / +40                      |
| Sundays River     | I    | 30            | 5                      | 20.2; -1 / +36                     |
| Swakopmund        | C    | 0             | 4                      | 20; 0 / +34                        |
| Swartkops Cerebos | I    | 10            | 4                      | 18.8; 0 / +35                      |
| Swartkops Salt    | I    | 3             | 4                      | 18.2; 0 / +35                      |
| Velddrif Cerebos  | C    | 12            | 5                      | 24.6; 0 / +40                      |
| Velddrif Salt     | C    | 12            | 5                      | 24.6; 0 / +40                      |
| Walvis Bay        | C    | 0             | 10                     | 20; 0 / +34                        |
| Yzerfontein       | S    | 80            | 0.5                    | 20; -2 / +38                       |

**Legend:**

I = Inland salt works; C = Coastal salt works; N = Natural coastal lagoon; S = Salt pan.
TABLE 3
Salt pans, salt works and lakes in East and Southern Africa with salinity values known to be greater than 40 g l⁻¹ (some sites have water only seasonally)

| Name                | Position       | Country         | Salinity | Reference                     |
|---------------------|----------------|-----------------|----------|-------------------------------|
| Annaspan           | 28°31'S - 25°48'E | South Africa    |          | Present study                 |
| Banksdrifpan       | 28°56'S - 25°14'E | South Africa    |          | Present study                 |
| Bogoria            | -              | Kenya           | 50       | Williams (1996)               |
| Britten Pan        | 27°45'S - 25°21'E | South Africa    | 181.6    | Seaman et al. (1991)          |
| Dealsville         | 28°40'S - 25°41'E | South Africa    |          | Present study                 |
| Delareyville area  | 26°41'S - 25°27'E | South Africa    |          | Present study                 |
| Etosha Pan         | 18°40'S - 16°40'E | Namibia         | 62.0     | Seaman et al. (1991)          |
| Florisdab Pan      | 28°45'S - 26°05'E | South Africa    | 197.3    | Seaman et al. (1991); Present study |
| Gannaleegte (3 sites) | 28°42'S - 25°52'E | South Africa    |          | Present study                 |
| Hoffontein         | 28°42'S - 25°52'E | South Africa    |          | Present study                 |
| Hosabes Pool       | 23°30'S - 15°05'E | Namibia         | 115.9 - 161.7 | Seaman et al. (1991)          |
| Karee Pan          | 27°30'S - 25°35'E | South Africa    | 41.8     | Seaman et al. (1991); Present study |
| Kimberley area     | 28°53'S - 24°15'E | South Africa    |          | Present study                 |
| Koppieskraal Pan   | 26°55'S - 20°18'E | South Africa    | 48.6     | Seaman et al. (1991)          |
| Magadi             | -              | Kenya           | 114      | Williams (1996)               |
| Mollerspan         | 28°53'S - 24°14'E | South Africa    |          | Present study                 |
| Natron             | -              | Tanzania        | 340      | Williams (1996)               |
| Oranjemund Pan     | 28°35'S - 16°35'E | Namibia         | 302.4    | Seaman et al. (1991)          |
| Rensburg Salt Pan  | 28°55'S - 26°05'E | South Africa    | 102.4    | Seaman et al. (1991)          |
| Skietbaana         | 26°43'S - 25°28'E | South Africa    |          | Present study                 |
| Skoppa             | 28°40'S - 26°05'E | South Africa    | 160.1    | Seaman et al. (1991); Present study |
| Soutbron           | 28°41'S - 25°50'E | South Africa    |          | Present study                 |
| Soutpan area (15 sites) | 28°42'S - 26°03'E | South Africa    |          | Present study                 |
| Stink Pan          | 27°46'S - 26°40'E | South Africa    | 51.1     | Seaman et al. (1991)          |
| Tara               | 28°42'S - 25°49'E | South Africa    |          | Present study                 |
| Wadrif Soutpan     | 32°12'S - 18°21'E | South Africa    |          | Present study                 |

Legend:
a = indicates sites visited where no Artemia were found
b = indicates sites which were dry at the time of the visit during the present study

were low, only numbers of males and females in parentheses, rather than percentage values, will be reported. These results can be used as an indication of the most likely reproductive status of the population since parthenogenetic populations do not have males, except for the rare occurrence of non-functional males (MacDonald and Brown, 1990). Therefore, these figures do not allow an estimation of the gender ratio in the population as this would require a larger sample size and repeated sampling at different times. They provide, however, a basis for hypotheses regarding a population’s reproductive mode.

In South Africa the sites Brandtvlei (10:47), Yzerfontein (13:33), Reynekespaaan (30:17), Swartkops Marina Salt (9:5), Swartkops Cerebos (7:7) and Missionvale (3:10) were inhabited either by sexually reproducing Artemia only, or they had at least one bisexual species. The presence of males in a population suggests the existence of a bisexual species, but the same site may also contain a parthenogenetic population. For example, Van Stappen (2002) listed the population from Swakopmund suggested the existence of a parthenogenetic population. At two sites in Namibia no males were recorded. These sites were Swakopmund (0:30) and Walvis Bay Salt Pan (0:42). Previously recorded Namibian populations (see Table 1) were parthenogenetic, and our recent records from the population at Swakopmund suggested the existence of a parthenogenetic population, thus confirming this reproductive mode for both sites using samples taken in 2003. Results from collections at Henties Bay (14:5) provide the first record of bisexual reproduction for Namibian Artemia although the species status of this population has not yet been determined.

Additional information (Table 2) was collected for some new southern African Artemia sites investigated as part of this study. This information included site management, GIS data relating average temperatures and their ranges, as well as elevation and the approximate area of the sites at the time of sampling. The latter value fluctuates strongly depending on season and rainfall and records should be taken repeatedly during the year.

Several other sites were visited but no Artemia or cysts were found (see Table 3). Of the 47 sites in South Africa and Namibia, 24 were at an elevation of above 1 000 m, with the highest elevation being 1 556 m a.m.s.l. Four sites were at sea level. The average elevation of the other sites was 793 m a.m.s.l. The average annual ambient temperature was 18.2°C (-8 to +42°C). The average minimum and maximum ambient temperatures of these 47 Southern African sites were -0.4°C and 36°C, respectively.
Site names

There are two South African populations at Swartkops; these are at Swartkops Marina and Swartkops Cerebos. These sites belong to different salt production companies and, although geographically close to each other, were not listed as being the same due to different management. Similarly, sites listed under the name Veldrif do not all belong to the same salt company. In addition, very similar names have been given to different sites; for example, the name Soutpan (Afrikaans for salt pan) appears as part of several composite names. Spelling may differ between Afrikaans and English (i.e., Coega or Koega).

Conclusion

There are 127 records of either sexually reproducing or parthenogenetic populations of *Artemia* on the continent, but reproductive mode has only been given for 41 populations. An estimated 32% of the populations appear to be parthenogenetic and 68% are bi-sexual species. However, only a tentative species list can be presented due to the uncertainty and paucity of published and anecdotal information. Most work on African *Artemia* populations needs verification using molecular techniques. Thus, applying caution with regard to the precision of the data, and considering that relatively few records are available, it is estimated that about 50% of the identified populations are *A. salina*, 12% can be hypothetically assigned to *A. franciscana*, and 38% of the populations so far described appear to be parthenogenetically reproducing *Artemia*.

By combining the information obtained during the sampling trips and climatic and GIS data available for South Africa with information provided in the literature the number of potentially available *Artemia* biotopes was updated (Table 3). These sites deserve further investigation. In order to obtain a representative picture of South African populations, sampling should be done repeatedly over several years and throughout the year since distinct dry seasons occur.

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