

Predominance of female babies on Niue Island – A sign of endocrine disruption?

Gary Mitchell *MBChB DCH Dip. Obs. Primex MPH*

'The potential repercussions of conditions that may alter the ratio of the sexes at birth should be considered a matter of utmost concern. The extent to which other adverse health consequences are linked to this phenomenon is a matter of grave importance for public health' (Davis et al 1998).

Abstract

In 2003, out of the first 18 babies born in Niue there were 17 females. The probability of this occurring by chance was 0.0000497. Birth data for the last 20 years in Niue suggests a decline in the proportion of boys over the last decade. Local health workers are suspicious that cancer rates in Niue are high, and that there may be a higher than expected incidence of infertility, menstrual problems, and miscarriages. Data for the latter conditions is poor. Overseas examples of altered sex ratios due to exposure to endocrine disrupting chemicals are researched and discussed, and the possibility of such a phenomenon occurring in Niue is raised. Although no specific causative environmental agent has been identified, questions are raised, particularly in relation to past dumped chemicals, and perhaps to the current widespread use of paraquat. The issue warrants further exploration. Recommendations for ongoing research and monitoring are made, as well as precautionary measures to be taken to limit potential adverse health effects in the meantime.

Introduction

Strong interest in the female:male birth ratio arose this year when it was noted that out of the 18 babies born in Niue from January to September 2003, 17 were females. Even with the small numbers involved, it seemed improbable that this would occur by chance. A brief literature search revealed some interesting material relating to altered sex ratios, from sources as diverse as reputable medical journals (Davis et al 1998, Mocarelli et al 2000) to popular interest books (Moore 2002) and environmental websites (Montague 1997). Some of this literature made reference to various environmental factors which may be responsible for altered sex ratio, and it is notable that some endocrine disrupting qualities of these chemicals can lead to such health problems as infertility, miscarriage and menstrual irregularities. These health issues feature prominently in the clinical caseload of local doctors in Niue, together with an impression that there is a high incidence of cancer in Niue. Many chemicals responsible for endocrine disruption can also cause cancer (Longnecker et al 1997). It was therefore considered important to examine available data and information about these conditions to determine whether in fact there was a higher than expected incidence in Niue, and to explore possible links between these conditions and local environmental factors, together with an examination of how these issues are currently being dealt with.

The author is a doctor who was working in the only hospital/health centre in at the time of writing. This is a small facility, in keeping with the size of the population. There are three doctors, 12 nurses, and 10 inpatient beds.

Niue is an isolated Pacific Island, consisting of an uplifted coral limestone plateau perched on top of a submerged volcano. Despite being the largest raised coral atoll in the world (26 square km), it is the smallest self-governing nation. Niue is situated approximately 480 km south west of Tonga, 660km south of Samoa, and 2400 km north east of Auckland. Niue is in free association with New Zealand, a relationship that stems from its colonial past. Niueans are Polynesian, with descendants from both Tonga and Samoa. The current population is close to 1700. There are 14 villages spread around the island. Eight of these are near the coastal area on the western side, and 6 are further inland on the eastern side. Some of the smallest villages have less than 100 inhabitants.

Niueans are New Zealand citizens and enjoy free access to New Zealand. This includes health services in New Zealand. Most Niueans live in New Zealand (close to 19,000), and there is a steady flux back and forth. However, the net effect is a dwindling population in Niue (see Table 1), and attempts to reverse this trend have been unsuccessful. With this dwindling population comes a reduced capacity to manage environmental concerns.

Table 1: population changes in Niue, 1981-2003

Date	1981	1984	1986	1989	1991	1994	1996	1999	2001	2003
Population	3281	2887	2531	2267	2239	2300	2089	1913	1788	1722

Source: Department of Statistics, Niue.

Note: Some of the above figures are inter-Census estimates.

Niue's climate is both tropical and marine, and provides relatively constant climatic conditions throughout the year. Tropical cyclones occur periodically in the summer months, and these have caused substantial damage in the past. Niue has a very fragile resource base. Isolation and the poor soil quality have limited the flora and fauna species varieties. Forested areas provide building materials for canoes and foodstuffs such as fruits, seeds, pigeons, bats and coconut crabs. However, an increasing part of the local diet comes from imported foodstuffs, including lots of processed foods. Corned beef remains a local favourite. The Huvalu rainforest is one of the largest remaining lowland forests in the Pacific. There are difficulties in establishing a fully protected forest and coastal area, and there are ongoing environmental issues that Niue faces as a result of an increasingly consumer-oriented lifestyle and moves from traditional practices to modern techniques in farming, fishing and forestry. For example, large areas of native land can now be cleared for taro planting in a matter of hours using bulldozers, whereas in the past taro would have been planted more interspersed with existing trees. The use of herbicides has largely replaced traditional weeding practices.

The population is said to be relatively healthy compared with other Pacific Island countries (Group 2000), ranked 2nd in the Pacific in terms of a range of health status parameters (such as infant mortality and life expectancy). However, economic constraints and the rising cost of health services are putting strain on services. The development focus at present centres on tourism, fishing and vanilla production. Transport is a problem for trade. Cargo is brought from New Zealand approximately every 3 weeks by ship. This is relatively expensive, and there are often delays, and often supplies are accidentally off-loaded in other destinations resulting in shortages in Niue (e.g. drugs and vaccines). Taro is a popular export crop, although financial returns are low compared to time and energy input, and taro growing is as much a local pastime and activity to supply local needs as it is an export activity.

Methods

A literature search was carried out using Pubmed, Cochrane database, and search engine Google.co.nz. Keywords used include sex ratio, trend, hormones, infertility, cancer and studies. Links from articles, websites, journals and other publications were also explored. Locally available publications were sourced from the libraries of DAFF and the Health Department, and from staff in the Public Health Division of the Health department.

Available data in Niue was examined, sourced from the Health Department (with permission of the Health Minister), DAFF, and Justice Department (births register), including historical data where available. This data was all paper-based. Interviews with DAFF workers past and present and public health staff were also useful.

Epidemiology and public health specialist expertise was used in the examination of probability and a wider inquiry was carried out via the Pacific Public Health Surveillance Network (PACNET), to investigate whether an altered sex ratio phenomenon had been noticed elsewhere in the Pacific.

The information gathered was then examined in an attempt to relate the observed change in sex ratio and other health phenomena to a range of environmental factors.

Limitations

Niue's population is only 1700, which means that calculated rates and percentages of health problems are liable to large fluctuations with only small numbers of cases. Therefore rates and comparisons must be interpreted with care. Another issue that would be interesting to explore if larger numbers were available is the issue of congenital birth defects.

In many instances, data has not actually been recorded e.g. cancer register. Health and environmental records in Niue have been poorly kept over the years. In the health department, computerization of records has only been initiated in 2003, and previous data is patchy and ill-organized.

The burning of environmental health and DAFF records resulted in a significant gap in data.

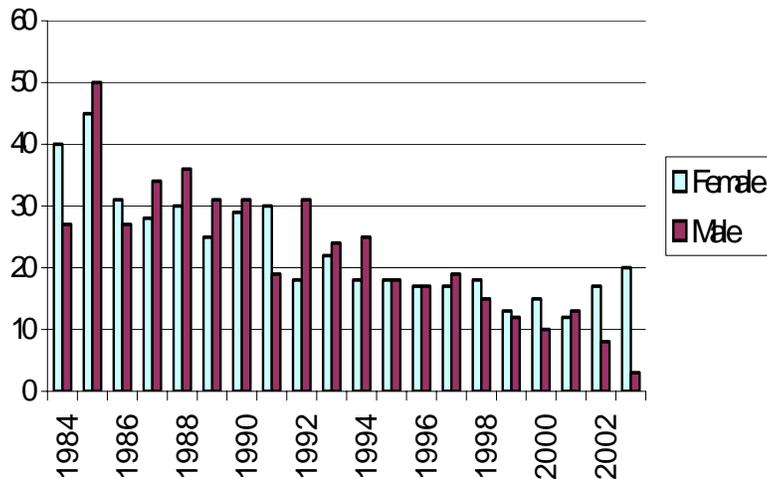
Results

Health issues in Niue

Sex ratio of newborns

The numbers of babies born in Niue has been decreasing steadily over the years with the declining population (Figure 1). However, the birth rate has also been decreasing (Figure 2). For a summary table of Niuean babies born in the past 20 years see Table 2.

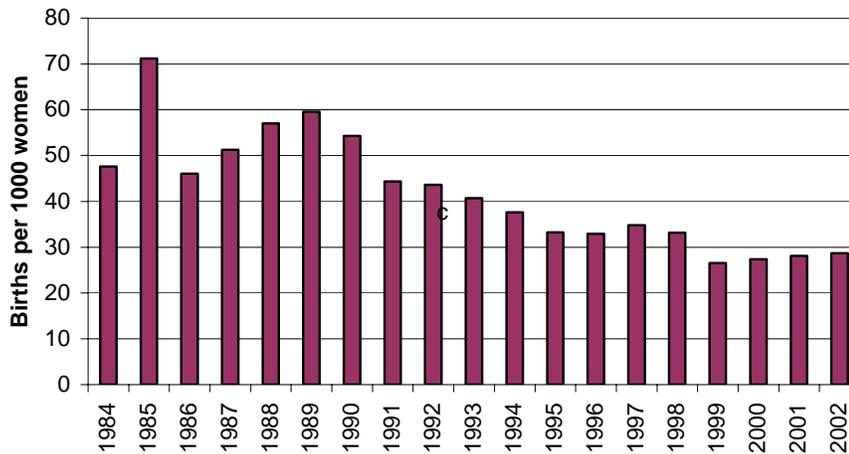
Figure 1: Numbers of Niuean female and male babies born per year 1984-2003



Data source: Births Register, Department of Justice

Notes: Births include those who fell pregnant in Niue but delivered in New Zealand. In some years the percentage of Niuean women delivering in New Zealand was up to 33%. Babies born in 2003 include babies born up to June only.

Figure 2: Birth rate (per 1000 population) for Niuean babies 1984-2002



Data source: Births Register, Department of Justice, estimated yearly denominator population from Department of Statistics, Niue

Notes: Births include those who fell pregnant in Niue but delivered in New Zealand. In some years the percentage of Niuean women delivering in New Zealand was up to 33%.

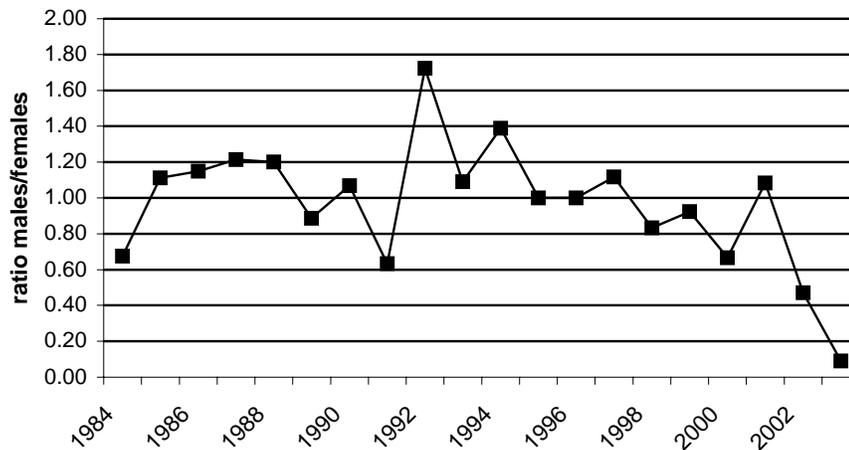
Table 2: Summary of Niuean babies born in past 20 years

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Grand Total
Female born Niue	13	22	14	18	17	19	15	13	9	15	9	10	9	12	12	10	11	12	14	16	264
Female born O/S*	1	2	2	1	2		6	2		3	2	1	4	1	2	2	2		3	3	36
Female living O/S**	26	19	15	9	11	5	7	15	9	4	7	7	4	4	4	1	1				148
Female – deceased		2				1	1										1			1	6
Total female	40	45	31	28	30	25	29	30	18	22	18	18	17	17	18	13	15	12	17	20	463
Male born Niue	11	20	11	21	20	18	18	10	18	11	16	10	7	10	10	5	10	11	7	1	245
Male born overseas*	3	2			2	6	2	3	4	4	2	2	2	2	1	3			1		39
Male living overseas**	12	28	16	13	14	7	11	6	9	9	7	5	8	7	3	3		2		2	160
Male – deceased	1											1			1	1					4
Total male	27	50	27	34	36	31	31	19	31	24	25	18	17	19	15	12	10	13	8	3	448
Male/female ratio	0.68	1.11	0.87	1.21	1.20	1.24	1.07	0.63	1.72	1.09	1.39	1.00	1.00	1.12	0.83	0.92	0.67	1.08	0.47	0.15	0.97
GRAND TOTAL	67	95	58	62	66	56	60	49	49	46	43	36	34	36	33	25	25	25	25	12	902

Data source: Births Register, Department of Justice
 O/S = overseas
 *means born overseas but since returned to Niue
 **means born overseas and still overseas

The decreasing numbers of births and the decreasing birth rate are likely to be mainly due to the dramatically decreasing population (see Table 1), increased use of contraception and preference for smaller family size. The possible influence of infertility and miscarriages is less easy to determine.

Figure 3: Sex ratio by year for Niue babies, 1984-2003



Data source: Births Register, Department of Justice

Notes: Births include those who fell pregnant in Niue but delivered in New Zealand. In some years the percentage of Niuean women delivering in New Zealand was up to 33%. The sex ratio here is expressed as the number of males divided by the number of females. The small numbers involved in this graph makes it difficult to quantify the trend significance.

Figure 3 demonstrates a trend in the last decade towards more girls and less boys. Interestingly it is still possible that the 2003 full-year result could be the converse of the 1993 result, which suggests that what may be happening is a wide chance variation due to small numbers.

In 2003 alone, there have been 17 female and one male baby born in Niue up to August. The chances of this occurring by chance (given that the probability of a male baby being born is approximately 0.51¹) is 0.49 [to the power of 17] multiplied by 0.51 (the probability for the one boy) multiplied by 18 (because there are 18 possible 'positions' for the boy in the sequence of 18 births). Thus the probability of the first 18 births in Niue in 2003 containing only one boy is

$$0.4917 \times 0.51 \times 18 = 0.0000497$$

Looked at another way, we could calculate whether getting, say, 15 girls out of 16 significantly deviates from the expected 50-50 ratio. A G-test is an adapted Chi-square test, which tells us if the found ratio of 15 girls out of 16 is significantly different from the expected 8 girls out of 16. The calculated value of the test (G value) is 14.70, for which using the Chi-square probability table shows that the chance that 15 out of 16 is actually a normal (8 out of 16) situation is 0.0001 (p-value), which is significantly different from the expected situation ($p < 0.05$).

Altered sex ratio in humans relating to a ubiquitous substance may be expected to cause similar effects in exposed animals (van der Schalie et al 1999). Other than the general impression of the author that there are far more female chickens than roosters in the local village in Niue, there is no data available to explore this issue in Niue!

Cancer

Small numbers in Niue make calculation of rates problematic. Surprisingly, there is no cancer register. However, there is a perception by local health workers that cancer numbers are high here, and of note is that in 2003 alone, 2 cases of leukemia and one of lymphoma were diagnosed up to August. These types of cancers in particular are suspected of being associated with environmental contamination such including POPs and radiation (Stewart and Kleihues 2003).

Comment was made that many of the agricultural workers from the period in the 1960's and 70's have died from cancer (personal communication, nurses and DAFF workers, August 2003). This period was

¹ The worldwide sex ratio slightly favors boys (Pyeritz 1998).

notable for the enormous quantities of agricultural chemicals imported and used, with little protection for workers (personal communication, Toeono, N. Coordinator, Persistent Organic Pollutants Programme, DAFF, Niue Island. August 2003).

Infertility, miscarriages and menstrual disturbances

There is very limited data relating to these health problems both in Niue and overseas. This partly relates to the fact that many women do not present to health services with these conditions. Menstrual disturbances and infertility are related to obesity (Birdsdale et al 1998), which is also common in Niue. Some women have early miscarriages without ever realizing they were pregnant, other women have irregular or heavy periods without seeking advice, and infertility may often not come to the attention of health services, nor is it well recorded for data collation. These issues are similar in overseas health systems, hence there is no good data for comparison and departure from norms is therefore impossible to determine.

As a result, we are left with the subjective impression of the author and other health workers in Niue that the numbers of women presenting with these conditions is unusually high given the population. As health workers, we can only compare with our experiences elsewhere and with our experience in Niue over time. The longest-serving current doctor in Niue has only been here for 6 years; therefore this clinical impression is difficult to correlate over time. Furthermore, periodic education and publicity sessions held via the media over the years has influenced the number of women coming forward for advice, as has the perceived approachability and expertise of doctors in Niue at any particular time.

Having said that, these clinical impressions should not be totally discounted given that they existed before the discovery of the altered sex ratio, and given the potential importance of the issue.

Current and past use of chemicals in Niue

Identifying the nature and extent of chemicals used in Niue proved to be surprisingly difficult. Interestingly, most records relating to past chemical use in the Departments of Health and Agriculture, Forestry and Fisheries have been burnt. Information has been pieced together from information supplied by current and past staff in these departments.

The 1960's and 1970's were the periods of most intense chemical use in Niue. DDT, 245T and chlordane were extensively used until the late 1970's, and there is some suggestion that DDT may have been used for much longer (unverified).

The chemicals in widespread use at present include:

Paraquat

This is an herbicide that has been used extensively in Niue for decades. There is plenty of anecdotal evidence from DAFF workers and users themselves that paraquat is often sprayed with no or inadequate protection, and it is this direct exposure that is the most likely source of human poisoning. Paraquat has not been shown in international studies to be an endocrine disruptor per se, though there is still uncertainty about this (Orme and Keglesy 2003). However, there is concern in many countries about possible side effects of paraquat, to the extent that it has been banned in some countries (Rahah and Surin 2002). Paraquat levels in groundwater in Niue were said to have been checked in 2000 by a Taiwanese company, though there is no documentation available. The levels were said to be negligible (personal communication, Hetutu, Environmental Health Officer, 2003). In the last 5 years, there has been considerable increase in the use of paraquat as taro export has been promoted. The take-home exposure risks of pesticides have been shown to be important (Curl et al 2002). No studies of human levels of paraquat or other pesticides have ever been carried out in Niue.

Round-up

This is used in Niue, though less extensively than paraquat. The chemical name is glyphosate and it has not been demonstrated to be linked to reproductive effects (EXTONET 1996).

Malathion

This is a recently introduced insecticide in Niue, being used for the last 5 years. It is mainly used by the Health Department for mosquito control, and although it is sprayed around dwellings, its use has been very sporadic and it is unlikely that on its own it would be responsible for a finding as pervasive as the altered sex ratio.

Rat poison

The author has experience of treating a number of people who have been directly exposed to Coumarin rat poison. This is often used inside houses and picked up on the soles of people living there. It is not a known endocrine disruptor, however.

Other

In Niue, inorganic chemical levels in groundwater were checked in 1996 and found to be within normal limits (Aharon 1996). Organic chemical levels have not been checked.

The use of other chemicals on a smaller scale by private users is not clear. Although chemicals brought in to Niue are required to be inspected by quarantine, there is the potential for people to import small quantities of chemicals unnoticed. However, it seems unlikely that the use of small quantities would be responsible for the health problems under investigation.

Obsolete Chemicals and Contaminated sites

An inspection of contaminated sites in Niue was carried out by the South Pacific Regional Environment Programme in 1998 (Burns et al 2000). The authors indicate that the management of chemicals, including pesticides, solvents, PCBs and waste oils has been recognized for some time as an environmental issue of major significance in the South Pacific region. Problems identified include:

- A lack of information on the types and volumes of chemicals being stored.
- A poor understanding of how chemicals should be used and stored.]
- Limited understanding of the threat of chemicals to the community and the environment
- An absence of appropriate disposal facilities
- A lack of resources directed at the problem

More specifically, the major findings of the inspection in Niue include the elements listed in Table 3.

Table 3: Sources and quantities of hazardous chemicals in Niue

Source	Estimated Quantity
Agricultural chemicals	1500 kg
Oil potentially contaminated with PCBs*	1000 L
Waste bitumen	Nil
Waste oil	Nil
Contaminated sites	1 site

*DAFF has indicated that this oil has been subsequently tested for PCBs and found to be PCB-free (personal communication, Toeono, N. Coordinator, Persistent Organic Pollutants Programme, DAFF, Niue Island. August 2003).

Of most significance are fertilizer stores because of issues relating to the very large volumes and poor storage. There is concern that many of the drums and packaging have corroded and that chemicals may be leaking and leaching into the environment. Because of the lack of records, it is also possible that there are unknown contaminated sites and even potential slow or increasing leaks from unknown sites. For example, there was mention of a report 20 years ago of DDT dumped in bush near the landfill site.

A survey has been completed by DAFF in August 2003, involving a questionnaire for previous agricultural workers. The findings confirm that in the past, widespread and unprotected use of pesticides occurred. Also, disposal of these chemicals was less than ideal, and several new contaminated sites were identified. These sites included caves where chemicals were dumped years ago. Preliminary site inspections revealed that in one cave a large unmarked drum has been leaking. At another site, DDT, dieldrin and 245T were believed to be present, with one site showing two 20-litre drums of 245T that were found to be empty. It is not known whether these have leaked over time or whether they have been empty since disposal. Another site showed a large quantity of fertilizer unsecured. The widespread use of creosote for treating timber was also revealed in the survey. The past disposal practices of this chemical are not clear. Some of the sites discovered as a result of the survey have not been explored for safety reasons. A team of experts from overseas is to come in to assess and secure the sites.

Discussion

Establishing a link between environmental factors and health problems is notoriously difficult at the best of times, and this paper is not claiming that such a link definitely exists in Niue in relation to the factors discussed. This paper signals the need for ongoing research in the area, together with the importance of applying ecological principles in the management of chemicals and contaminated sites. Such activities are already well in hand under the wing of DAFF, and the recent community awareness campaign relating to POPs is an encouraging sign that these issues are going to be taken seriously. On the other hand, there is much to be done, including the need to reinforce personal protection in the use of paraquat and other chemicals on small-scale bush gardens. The true extent of past chemical dumping in Niue remains unknown, and may be the key to the health effects under study.

The 'normal' sex ratio may be expressed as the male proportion, or the number of male births divided by total births, and the current worldwide ratio is said to be 0.515 (Pyeritz 1998). Another sex ratio measurement method is to say that for every 100 female births, there are believed to be 106 male births. This yields a sex ratio of 1.06. In many countries there is a continuing change in the birth sex ratio towards a female predominance. In some places this is seen as a gradual but statistically significant trend over many years (Moller 1996, Allan et al 1997, van der Paul-de Bruin et al 1997). This trend is very gradual, for example in the order of a reduction of the sex ratio in the U.S.A from 1.052 to 1.048 over the last 20 years (NCHS 2002). The important issue is whether this is a 'natural' phenomenon of little consequence, or whether this is an important 'sentinel' health event (Davis et al 1998). Other researchers have described dramatic localized changes within countries and have attempted to explain this in terms of environmental influences (van der Pal-de Bruin 1997, Moller 1998).

Sexual differentiation takes place between weeks 6 and 9 of human life (Davis et al 1998), and it is during this time that the postulated influence may occur. At the moment of conception, all embryos are destined to be female unless something changes them into males. Between the 6th and 9th week, the gonads of those with a Y chromosome specialize into testicles and begin producing hormones that continue the process of creating a male. If anything interferes at this stage, a female may result. Thus sex is determined by tiny amounts of hormones circulating in the blood of the embryo. This situation provides opportunities for chemicals entering the mother's body ("xenobiotics") to disrupt normal processes (Montague 1998).

Some researchers contend that the father's exposure level is the best predictor of sex of the offspring (Mocarelli et al 2000, Del Rio Gomez et al 2002, Ryan et al 2002). Mocarelli (2000) also determined that fathers exposed to dioxin at a young age (younger than 19) were significantly more likely to have daughters than sons if their exposure to dioxin was relatively high.

Other general medical factors and conditions documented to reduce the male proportion of offspring include older age of fathers, in vitro fertilization, non Hodgkin lymphoma, hepatitis, use of fertility drugs such as clomiphene, increase in maternal and paternal age, exposure to the nematocide dibromochloropropane, work in the aluminum industry, organochlorine pesticides, and stress (Davis et al 2000).

Some researchers dispute the link between environmental chemicals and altered sex ratios (Vartiainen et al 1999); although most acknowledge that there is a possibility. A summary of the main theories that may be relevant for Niue follow.

Main theories for Niue

Endocrine disruption by chemicals

Many studies have demonstrated a link between chemicals and the kind of endocrine disruption that may be responsible for altered sex ratios (Del Rio Gemex 2002, Ikezuki et al 2002, Weisskopf et al 2003). The chemical groups include dioxins and dioxin-related chemicals such as polychlorinated biphenyls (PCBs) and aluminum (Mocarelli et al 2000, Del Rio Gemex 2002). In Italy, stunning evidence of reproductive effects emerged from the ongoing investigation of the human health consequences of the explosion at a chemical factory in Seveso in 1976. The dioxin released in this accident contaminated thousand of people in the surrounding city and left some with the highest dioxin levels ever measured in humans. In examining the children born to parents with high dioxin exposure from April 1977 to December 1984, researchers discovered a highly skewed sex ratio: these parents produced only 26 boys to 48 girls (Mocarelli et al 1996). Pesatori et al (2003) confirmed these findings, together with an increase in cancers and endocrine disorders.

Prominent in the Niuean diet are taro (with risk of pesticide contamination), fish and a range of imported foods including canned corned beef and powdered milk. Hormone-disrupting effects from these products are unlikely to be responsible for the observed sex ratio effect in Niue, given that exposure has not changed significantly in the last 10 years, and the lack of an observed effect in other Pacific countries with similar diets.

Other common practices such as mosquito coil use, burning and incineration of regular and clinical waste, smoke and cooking residue, and diet are unlikely to be of any importance since they are no more prevalent than in other Pacific countries. Despite this, it is plausible that a cumulative effect may have occurred involving a constant exposure to one of the above factors, but perhaps more likely is an increase in exposure in recent years, whether overt or covert.

Encouragingly, the risks of chemical exposure have recently gained a higher profile in Niue with the launch of a public awareness program on POPs, coinciding with the adoption of the principles of the Stockholm Convention on Persistent Organic Pollutants 2001. The management of hazardous chemicals in Niue is under the jurisdiction of the DAFF and the Department of Health. Current management includes securing and isolating contaminated sites and shipping chemicals off island.

It is important to emphasize that factors other than chemicals may be responsible for the sex ratios and health parameters discussed. More than one factor may be responsible. In particular, chance alone may be responsible, despite the statistical significance shown in the calculations.

Furthermore, the relevant factor(s) may be past rather than current, which, given the paucity of DAFF and Health Department records, may be difficult to uncover. Some researchers have suggested that the important period of exposure may be some time in the past (Mocarelli et al 2000, Ryan et al 2002), and therefore measurement of current blood or environmental levels in Niue may not reflect the situation that led to this phenomenon.

Older parents

The older the parents, the more likely the offspring will be a girl (Davis et al 1998). There is a trend in many countries, especially in the developed world, towards women having their first baby at an older age. The relevant data for Niue has not been extracted, though there is a general perception amongst health workers that maternal age is increasing. The effect from this, however, is very slight and alters the overall sex ratio by only a fraction of a percent.

Radiation

Niue has naturally-occurring uranium, a source of radiation. Niue's naturally occurring uranium and radiation levels have been sporadically looked at in the past (Richmond-Rex and Cooper 2001). In 1996 groundwater radiation levels were checked from a number of sources around the island and found to be within WHO guidelines (Aharon 1996). The reproductive effects of radiation are well-documented (Davis et al 1998), but among them there is no mention of altered sex ratio.

Chance

Despite the dramatic sex ratio figures, it is important to consider that there may not actually be a problem! The likelihood of this is diminished since Niue's closest neighbor, Samoa, is ranked fourth in the world in terms of male predominance with a sex ratio of 1.39 (Anon 2003). PACNET communication from a number of other Pacific Islands has so far not revealed a similar trend elsewhere.

Implications

Regardless of the cause of the apparent ratio, parents in Niue are already asking questions about the impact on their children as they grow up and, for example, only have one male in the entire classroom at school. It is difficult to know the overall social and economic impact that this trend could have if it continues.

Environmental activists make the point that just because an effect has not been proven, that doesn't mean it does not exist (Montague 2003). This leads to the idea of the precautionary principle which says:

If you have reasonable suspicion of harm, and you have scientific uncertainty, then you have a duty to take action to prevent harm, by shifting the burden of proof of safety onto those people whose activities raised the suspicion of harm in the first place, and evaluating the available alternatives to find the least harmful way, using a decision-making process that is open, informed, and democratic and that includes the people who will be affected by the decision.' (Montague 2003).

Niue has a small population, and it should be remembered that other countries with 'normal' sex ratios may contain pockets or small areas where the sex ratio deviates from the norm. One avenue of research would be to explore regional differences within other Pacific Island countries. If the length of time that a woman or a man lives in Niue before conceiving is important, for example for a cumulative exposure, the numbers in Niue would be too small to be able to demonstrate this. Therefore a study in Niue of mothers and their partners looking at exposures and behaviors would be at best indicative, but more likely fruitless.

Despite the uncertainty relating to the quality of data and small numbers involved, the issue is important and worrying enough to take seriously. There is the possibility of some kind of serious anthropogenic environmental influence causing endocrine disruption and possibly other health effects in Niue. No particular chemical has been identified though paraquat is known to be widely used with little user protection, and chemicals are known to have been dumped in sites now hidden and overgrown. More study and monitoring are required to determine this.

Recommendations

- Prioritization of ongoing research into the issue by DAFF and the Health Department.
- Pesticide residue testing of soil, water, food and humans, with priority on water and human testing. This is already happening within DAFF, and involves the calling in of 'experts'.
- Improved documentation of current chemical usage. This is the responsibility of DAFF, and is well within their capacity.
- Investigation and remediation of existing and recently discovered contaminated sites carried out as a high priority.
- Improvement of health condition recording by the Health Department, including an accurate rolling cancer register and computerization of all relevant obstetric and neonatal data. This data needs to be tracked carefully over time, with ongoing analysis looking at the significance of sex ratio trends and rates of other health conditions.
- Immediate health promotion action to ensure that current chemical use is safer. This includes promoting the use of protective clothing and techniques for users, as well as education in relation to safer effective alternatives to chemical use.
- Compliance with the recommendations of both the Stockholm Convention (SCPOP 2001) and the report of the visiting inspection team in 2000 regarding the safe use of chemicals and the safe disposal of known chemicals in Niue.

References

- Aharon P. (1996) Niue Groundwaters: Chemical and Isotope Analyses. Louisiana State University, Louisiana.
- Allan BB, Brant R, Seidel JE, Jarrel JF (1997) Declining sex ratios in Canada. *Can Med Assoc J.* 156:37-41.
- Anon (2003) Geography IQ website. http://www.geographyiq.com/ranking/ranking_Sex_Ratio_total_population_dall.htm (accessed 08/03). Based on public domain works from the U.S. Dept. of State and the CIA World Fact Book.
- Berkowitz GD (1992) Abnormalities of gonadal determination and differentiation. *Semin Perinatol.* 16:289-298.
- Birdsdale M, Ellis J, Fisher J, Graham F, Irwin R, Peek J, Uddell H. (1998) Making Babies. A New Zealand Guide to Getting Pregnant. Fertility Associates. Auckland.
- Curl C, Fenske R, Kissel J, Shirai J, Moate T, Griffith W, Coronado G, Thompson B (2002) Evaluation of Take-Home Organophosphorus Pesticide Exposure among Agricultural Workers and Their Children. *Environmental Health Perspectives* 110:A787-92.
- Burns T, Graham B, Munro A, Wallis I (2000) Management of Persistent Organic Pollutants in Pacific Island Countries. Waste and Obsolete Chemicals and Chemical Contaminated Sites. South Pacific Regional Environment Programme.
- Davis DL, Gottlieb MG, Stampnitzky JR (1998) Reduced ratio of male to female births in several industrial countries: A sentinel health indicator? *Journal of the American Medical Association* 279:1018-1023.
- Del Rio Gomez I, Marshall T, Tsai P, Shao Y-S, Guo YL (2002) Number of boys born to men exposed to polychlorinated biphenyls. *Lancet* 360: 143-44.
- EXTONET (2003) Extension Toxicology Network. Pesticide Information Profiles. Glyphosate.

- <http://ace.ace.orst.edu/info/extoxnet/pips/glyphosa.htm> (accessed 10/03). Oregon State University. Revised June 1996.
- Group BF (2000) Healthy and Safe Niue. An NZODA sponsored Niue Health Sector Development Project. Project implementation document. National Institute of Health and Safety: Wellington.
- Ikezuki Y, Tsutsumi O, Takai Y, Kamei Y, Taketani Y (2002) Determination of bisphenol A concentrations in human biological fluids reveals significant early prenatal exposure. *Hum Reprod.* 17:2839-41.
- Longnecker MP, Rogan WJ, Lucier G (1997) The human health effects of DDT (dichlorodiphenyltrichloroethane) and PCBS (polychlorinated biphenyls) and an overview of organochlorines in public health. *Annu Rev Public Health.* 18:211-44.
- Mocarelli P, Brambilla P, Gerthous PM, Patterson DG Jr, Needham LI (1996) Change in sex ratio with exposure to dioxin. *The Lancet* 348:409.
- Mocarelli P, Gerthous PM, Ferrari E, Patterson DG Jr, Kieszak SM, Brambilla P, Vincoli N, Signorini S, Tramacere P, Carreri V, Sampson EJ, Turner WE, Needham LL (2000) Paternal concentrations of dioxin and sex ratio of offspring. *The Lancet* 355:1858-1863.
- Moller H (1996) Change in male:female ratio among newborn infants in Denmark. *The Lancet* 348:828-829.
- Moller H (1998) Trends in sex-ratio, testicular cancer and male reproductive hazards: Are they connected? *APMIS* 106:232-239.
- Montague P (1997) Something is Terribly Wrong. *Rachel's Environment & Health News* #576. <http://www.rachel.org/search/index.cfm?St=1>. (accessed 09/03).
- Montague P (1998) Missing Boys. *Rachel's Environment & Health News* #594. <http://www.rachel.org/search/index.cfm?St=1> (accessed 09/03).
- Montague P (2003) Environmental Justice and Precaution. *Rachel's Environment & Health News* #770. <http://www.rachel.org/search/index.cfm?St=1> (accessed 09/03).
- Moore M (2002) *Stupid White Men*. Penguin Books, Sydney.
- NCHS (2002). National Vital Statistics Reports, National Center for Health Statistics, 51(2) <http://www.infoplease.com/ipa/A0005083.html> (accessed 10/03).
- Orme S, Kegley S (2002) PAN Pesticide Database, Pesticide Action Network, North America (San Francisco, CA.), <http://www.pesticideinfo.org>. (accessed 09/03).
- Pesatori AC, Consonni D, Bachetti S, Zocchetti C, Bonzini M, Baccarelli A, Bertazzi PA (2003) Short- and long-term morbidity and mortality in the population exposed to dioxin after the "Seveso accident". *Ind Health.* 41:127-38.
- Pyeritz RE (1998) Sex: what we make of it. *JAMA.* 279:279:269.
- Richmond-Rex P, Cooper T, Nemaia J, Butler D (2001) Niue National Biodiversity Strategy and Action Plan. Alofi., Environment Unit. Department of Community Affairs, Niue.
- Ryan JJ, Amirova Z, Carrier G (2002) Sex Ratios of Children of Russian Pesticide Producers Exposed to Dioxin. *Environmental Health Perspectives* 110:A699-A701.
- SCPOP (2001) Convention text. Stockholm Convention on Persistent Organic Pollutants, http://www.pops.int/documents/convtext/convtext_en.pdf. (accessed 9/03).
- Stewart B, Kleihues P (2003) World Cancer Report. World Health Organisation. IARC Press, Lyon.
- van der Pal-de Bruin KM, Verloove-Vanhorick SP, Roeleveld N (1997) Change in male-female ratio among newborn babies in Netherlands. *Lancet.* 349:62.
- van der Schalie W, Gardner Jr. H, Bantle J, De Rosa C, Finch R, Reif J, Reuter R, Backer L, Burger J, Leroy C, Folmar L, Stokes W. (1999) Animals as sentinels of human health hazards of environmental chemicals. *Environmental Health Perspectives* 107:309-316, <http://ehp.niehs.nih.gov/docs/1999/107p309-315vanderschalie/abstract.html>, (accessed 6/04).
- Vartiainen T, Kartovaara L, Tuomisto J (1999) Environmental Chemicals and Changes in Sex Ratio: Analysis Over 250 Years in Finland. *Environmental Health Perspectives* 107:813-816, <http://ehp.niehs.nih.gov/docs/1999/107p813-815vartiainen/abstract.html> (accessed 6/04).
- Weisskopf M, Anderson H, Hanrahan L (2003) Decreased sex ratio following maternal exposure to polychlorinated biphenyls from contaminated Great Lakes sport-caught fish: a retrospective cohort study. *Environmental Health: A Global Access Science Source* 2:2, <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=153540&rendertype=abstract> (accessed 6/04).