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THE EFFECTS OF COMMERCIAL FISHING, TOURISM AND CLIMATE CHANGE ON MAGELLANIC PENGUIN POPULATIONS IN CHILE, ARGENTINA AND THE FALKLAND ISLANDS

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ABSTRACT

Magellanic penguins (*Spheniscus magellanicus*) only breed in Chile, Argentina and the Falkland Islands. Our research compares the status of colonies in each of these countries. On Magdalena Island in Chile, an increase from 59,000 pairs in 2000/01 to 63,000 pairs in 2008/2009, was reversed by a severe drought in 2009, causing a decline to 43,000 pairs by 2018/19. This decline goes against the regional trend. The neighbouring colony on Contramaestra Island was not affected by the drought and has increased from 400 pairs in 1990/91 to 26,000 pairs by 2019/20. Argentina's second largest colony at Cabo Vírgenes has increased from 89,000 pairs in 1987/88 to 146,000 pairs in 2019/20. Other colonies in southern Argentina are stable or increasing. Two colonies in Chubut have declined due to commercial fishing and oil pollution. Overall populations in Chile and Argentina remain healthy and stable. Populations in the Falkland Islands have declined by 92% from 1,300,000 pairs in 1989/90, to 100,000 pairs in 2019/20, following the establishment of the Falkland Islands Government's commercial fishing industry in 1988. Penguins show slightly higher breeding success in the presence of tourism. Tourists scare away predators that would steal eggs and chicks from the penguins.

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INTRODUCTION

Population studies estimate that the world population of Magellanic penguins (*Spheniscus magellanicus*) is between 1.3 and 1.7 million breeding pairs, with approximately 700,000 pairs in Chile, 900,000 pairs in Argentina and 100,000 pairs in the Falkland Islands (Falabella and Campagna (Eds) 2019, Bingham 2020). One of the best known breeding sites for Magellanic penguins in Chile is located on Magdalena Island in the Straits of Magellan (Fig 1). Magdalena Island is a popular tourist destination, with an average of 2,500 tourists visiting the island each week during 2019. Park wardens live in the lighthouse at the centre of the island and protect the island throughout the breeding season. Tourists arrive by boat in groups of up to several hundred at a time, and follow a set path around the island. Tourists are allowed just one hour ashore by the tour operators, and are accompanied by professional guides. Penguins have an average of two or three visits per day, and there is a complete absence of tourists on the island between these scheduled visits. Just 18km. from Magdalena Island there is another important penguin colony on Contramaestra Island. The flat, wind-swept island of Contramaestra is unoccupied and has no building suitable for shelter, and is further away from the nearest town, so there is no formal tourism on Contramaestra Island. Cabo Virgenes in Argentina is open to the public but visitor numbers are low and there are no tour operators visiting the colony. The nearest town of Rio Gallegos is small and has little tourism, so visitors to the colony are mostly local. Access to the colony is by vehicle along a severely degraded dirt track that is 115 kilometres long, and more suited to off-road vehicles than cars, so visitor numbers are low, averaging about 30 per week during 2019. Long-term population studies began at Cabo Virgenes in 2003. Other colonies in Argentina under observation are Monte Leon, Isla Leones, Punta Entrada, Isla Cormoran, Bahia Laura, Punta Buque, Isla Pinguino, Puerto Deseado, Punta Tombo and Peninsula Valdez.

Long-term penguin population studies in the Falkland Islands began in 1989, after the establishment of the Falkland Island Government's commercial fishing industry in 1988. The Falkland Islands received 62,500 cruise ship visitors during 2018/19, most of whom visited the Magellanic penguin colony located at Gypsy Cove. Volunteer Point has much fewer visitors due to the greater distance from Port Stanley. Other colonies under study around the Falkland Islands have few or no tourists, including Hadassa Bay, Bull Point, Fanning Head, West Point Island and Saunders Island. The aim of this study is to monitor and compare Magellanic penguin population trends and breeding success in Chile, Argentina and the Falkland Islands, and to compare the impact of commercial fishing, tourism and other potential threats under the different management of each country.

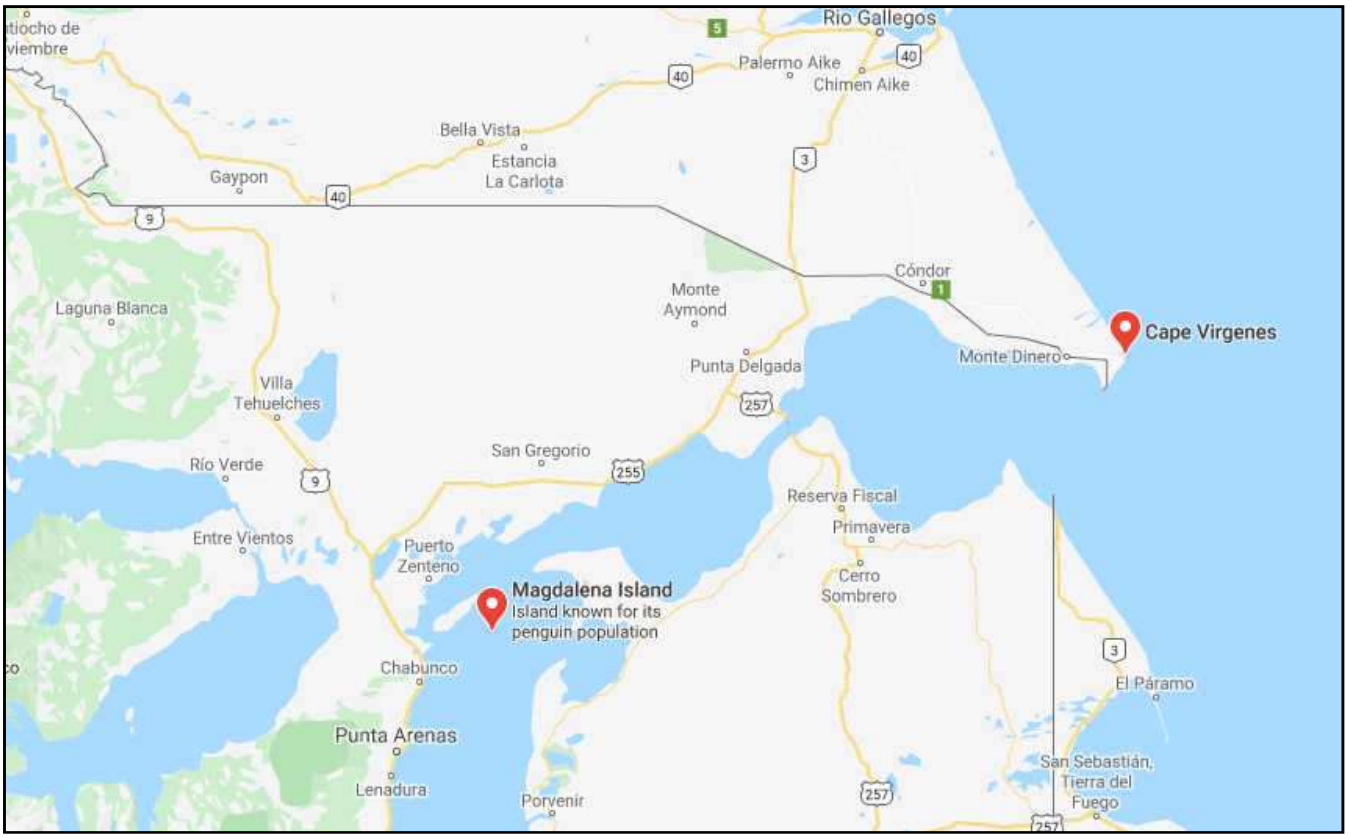

Figure 1: Map indicating location of Magdalena Island and Cabo Virgenes

MATERIALS AND METHODS

Because Magellanic penguins live below ground in burrows, and over such a large area, direct nest counts are not possible. Many burrows are unoccupied, or are occupied by non-breeding single adults, so to assume that all burrows contain nests would greatly over-estimate the population size. To count breeding pairs it is necessary to look inside each burrow to confirm the presence of eggs shortly after laying, using a telescopic camera or by putting one's head into the burrow. If eggs are not visible, the penguin is gently lifted using a wooden pole to allow confirmation of at least one egg. Counted burrows are marked with a small spot of paint to keep track of which burrows have been counted and which have not, to avoid missing or double-counting burrows.

For Magellanic penguins it is necessary to establish fixed study plots to obtain long-term population data (Hiscock, 1993, Bingham, 2004, Bingham, 2020, Bingham and Herrmann, 2009). In Chile, studies began on Magdalena Island in 1998 and on Contramaestra Island in 2002. Habitat maps were prepared of terrain and soil type, along with population censuses of all bird and mammalian species found on each island, to provide background baseline data of the islands (Bingham and Herrmann, 2009). Fixed study-plots were established to estimate penguin population and to observe trends. Every single burrow within each plot was examined each year in late October, directly after egg-laying, to determine the number of occupied nests, and this was used to estimate the average breeding density in nests per square metre. The nesting area was mapped out using a GPS, and multiplying the breeding area in square metres, by the average number of nests per square metre, an estimate of the colony's population size was obtained for each census. The greatest margin of error in determining population size using this method is in the assumption that breeding density recorded in the plots is representative of the entire colony. By using long-term fixed-location study plots year after year, this margin of error is eliminated when looking for *changes* in population size. Even minor changes in breeding density, and hence population size and trends, can be measured with accuracy using fixed study plots, even though a greater margin of error is implied when extending this to defining an actual population size in any particular year (Hiscock, 1993). In addition to studying population changes, in late October, shortly after egg-laying, around 20 occupied nests in each plot were marked, and these nests were visited regularly throughout the season, to determine what proportion of eggs and chicks survive, the major causes of egg and chick loss, chick weight and how much food chicks are fed. In addition to the study plots, occupied nests alongside the tourist path were also marked and studied, to investigate whether the presence of tourists causes changes in these parameters. Adults incubating eggs and chicks were marked in their burrows using red and blue non-toxic animal marker crayons on long poles, so that each partner could be identified during hourly observations. These markings were placed on the throat where they were easily visible during nest inspections, and where they could not be removed or ingested during preening. Hourly observations recorded time spent in and away from the nest for each partner during egg incubation and chick rearing.

The same methodology was employed to study Magellanic penguin populations in Argentina at Cabo Vírgenes since 2003 (Fig. 1). Unlike the Falkland Islands and Magdalena Island, penguins at Cabo Vírgenes do not use burrows and nest above ground underneath bushes instead of making burrows. Nests alongside the tourist path were also marked and studied to look for differences caused by the presence of visitors. Other colonies in southern Argentina were monitored at Monte Leon, Isla Leones, Punta Entrada, Isla Cormoran, Bahia Laura, Punta Buque, Isla Pinguino, Puerto Deseado and Punta Pajaros. The same methodology was used to study Magellanic penguin populations in the Falkland Islands since 1989, with fixed study plots at Gypsy Cove, Hadassa Bay, Bull Point, Volunteer Point, Fanning Head, West Point Island and Saunders Island. Diet samples were taken of Magellanic penguins using the stomach-flushing technique (Wilson, 1984). Samples were taken during chick-rearing from adults returning to the colony with food for the chicks. Stomach samples were drained and stored in jars with formaline solution or alcohol, ready for later examination. Once in the laboratory the stomach samples were rinsed with water, drained to remove any

excess liquid, and weighed to determine the wet weight of food retrieved. Each sample was then divided up into its appropriate components, which were weighed individually to determine proportional dietary composition by wet weight. Fish otoliths, cephalopod beaks and crustacean carapaces (which are not digested) were used to aid species identification, and to estimate proportional composition. These data were then compared with the Falkland Islands Government fisheries catch statistics in order to determine the level of overlap between penguin diet and commercial fishing activities.

RESULTS

Chile: Seven fixed study-plots were established on Magdalena Island to estimate penguin population trends. These plots indicated populations of 59,000 breeding pairs in 2000/01, 63,000 pairs in 2008/09, and 43,000 pairs in 2018/19 (Table 1). Magellanic penguins make their nests in burrows on Magdalena Island. Prior to the drought of 2009 penguins nested over almost the entire island, so population increases could not occur as a result of increases in nesting area, only through increases in nesting density, which is limited for penguins that nest in burrows. The island had short grass with deep roots that stabilised the soil enabling the excavation of burrows over most of the island. In 2009 and 2010 the island suffered a severe 18 month drought that killed off all the vegetation leaving just bare soil. Without any surviving vegetation, the wind caused loose soil to be blown across the island (Fig. 2), covering and burying burrows, eggs and chicks (Fig. 3). This caused very low breeding success, and reduced the available nesting area of the island.

Figure 2: Dust storm sweeping the island after the drought

Figure 3: Penguin burrow being buried during dust storm

Vegetation has gradually returned to the island over the years, but the new vegetation is made up of different species, with deep rooting species being replaced by drought resistant species that have superficial surface roots adapted to take advantage of short rain showers. This new vegetation is now a thin top-layer with shallow roots, overlying deep layers of fine dusty soil deposited over much of the island by years of dust storms following the drought. The situation is aggravated by a network of voids underneath the surface which are the result of old abandoned burrows that were buried during the dust storms. Penguins trying to dig burrows are now unable to do so in many of the flat plains, because the soil just collapses. This has reduced both the available nesting area of the colony and the nesting density, with a subsequent reduction in population. During 2018/19 a comparison of the fixed plots indicated large population changes since 2008/09. Five of the seven plots showed a decline in the number of occupied nests, ranging from -20% to -60% (Table 1). However an increase of 10 to 20% in the number of occupied nests was observed in two plots (Table 1). The majority of the decline on Magdalena has occurred in the flat valleys, with the hills showing a slight increase in population. Plots 1, 4 and 5 are all very similar except for their location. They are all located in flat plains where the worst of the drought occurred. The loss of all the vegetation on the island during the 2009-10 drought caused the wind to lift the fine loose soil and deposit it in these valleys and plains, filling up the burrows, covering the nests, and causing the loss of many burrows. In 2019/20 these areas featured a shallow top-layer of new vegetation with shallow roots, over-lying thick deposits of fine dusty soil that is unsuitable for burrows.

These three plots have registered the highest population decreases on the island. Plots 1 and 5 are linked by the large plain located between the lighthouse and the jetty where tourists circulated, while Plot 4 is located on the opposite side of the island where tourists never visit. The plots were chosen to observe differences caused by the presence and absence of tourism in these types of flat terrain. Plots 2 and 3 are also very similar to each other. They are both flat but have firmer soil and better vegetation, making them more suitable for burrows. Plot 2 is exposed to low presence of tourists while Plot 3 has zero contact with tourism. The decrease in penguins is much lower in both these areas. Plots 6 and 7 are both on top of hills and both are very similar in terrain, slope and aspect. They are on opposite sides of the island. Plot 6 has zero contact with tourism, while Plot 7 has tourists crossing between the plot and its access to the sea. However both plots have registered an increase in population.

During 2018/19 the mean breeding success on Magdalena Island was 0.74 chicks per nest (range = 0.34 to 1.60), which indicates that 37% of all eggs laid survived to produce a juvenile that fledged successfully (Table 3). Compared to that figure for the island as a whole, nests placed within two meters of the tourist path had a breeding success of 1.18 chicks per nest, which indicates that 59% of eggs placed very close to tourists survived. Nests within 2 metres of the tourists were 50% more successful than nests situated well away from tourists (Table 3). This breeding success of 1.18 chicks per nest observed near to the tourist path is not only high for 2018/19, it is also high compared to any year for Magdalena in general. Excluding the tourist path, Magdalena Island has not had breeding success of 1.18 in any plot since 2007/08 which was before the drought (Table 3). Plot 1 is directly located below the lighthouse and is the plot with the highest presence of tourists compared to any other plot on the island. Despite suffering a reduction in nesting density since the drought, during 2018/19 the penguins remaining in Plot 1 had the highest breeding success on the entire island by far. Plot 1 was 60% more successful than any other plot on the island, with an average of 1.6 chicks per nest. A breeding success of 1.6 chicks per nest is exceptional, so exceptional that in 20 years of studies on Magdalena Island only penguins nesting alongside tourists have ever registered such a high level of breeding success.

During 2018/19 the breeding success in Plot 1 was more than double the average for the entire island, and raised more chicks per nest than any other plot during the 20 year study period. By comparison, the

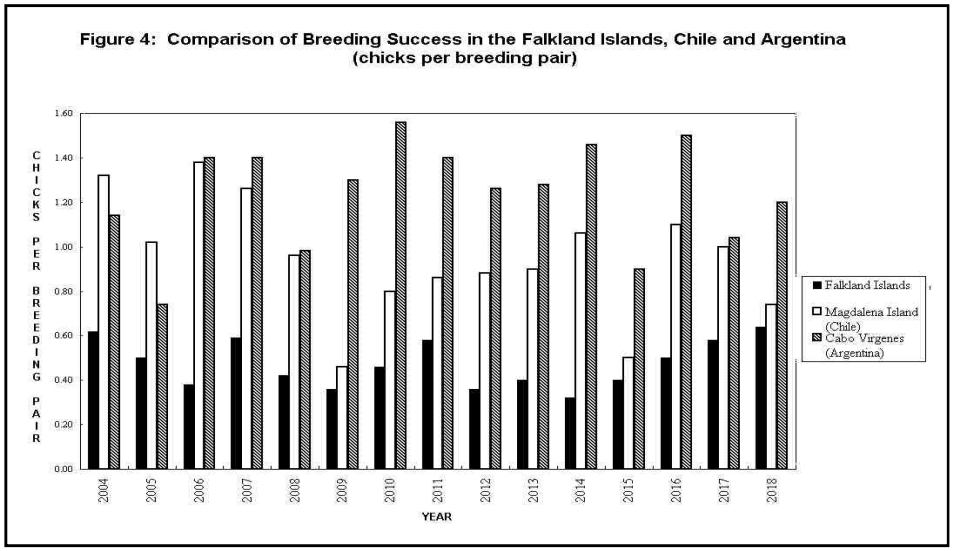

Table 1: Magellanic penguin population on Magdalena Island - 2000/01 to 2018/19 (Number of Occupied Nests)

PLOT	2000/01	2008/09	2018/19	CHANGE
1	254	264	105	- 60%
2	151	171	140	- 20%
3	192	240	190	- 20%
4	222	270	160	- 40%
5	259	277	140	- 50%
6	37	51	60	+ 20%
7	145	175	190	+ 10%
POPULATION	59,000	63,000	43,000	

Table 2: Magdalena island breeding success (chicks fledged per breeding pair)

Plot	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	1.10	1.30	0.72	1.08	1.44	1.00	1.46	1.50	1.00	0.30	0.84	1.10	0.50	0.76	1.00	0.58	0.96	1.00	1.60
2	1.14	1.66	0.24	0.96	1.24	1.00	1.66	1.00	0.66	0.60	0.68	0.88	1.00	1.20	1.00	0.54	1.12	1.00	0.86
3	1.41	1.52	0.52	0.88	1.00	1.06	0.92	1.40	1.34	0.34	0.70	0.32	0.40	0.58	1.30	0.66	0.90	1.22	0.34
4	0.89	1.35	0.28	0.60	1.32	1.16	1.44	1.10	0.90	0.42	0.58	D	D	D	D	D	D	D	0.50
5	1.30	1.08	0.62	0.68	1.50	1.42	1.42	1.50	1.00	0.50	0.80	0.34	1.30	0.90	A	A	A	A	A
6	1.15	1.32	0.30	1.14	1.30	0.80	1.28	1.26	0.76	0.80	0.82	0.80	1.20	0.80	1.00	0.54	1.14	0.74	0.50
7	1.17	1.36	0.26	0.82	1.50	0.70	1.38	1.00	1.00	0.30	1.12	0.68	0.88	1.20	1.02	0.60	1.40	1.04	0.72
Mean	**1.16**	**1.38**	**0.42**	**0.88**	**1.32**	**1.02**	**1.37**	**1.26**	**0.96**	**0.46**	**0.80**	**0.86**	**0.88**	**0.90**	**1.06**	**0.58**	**1.10**	**1.00**	**0.74**
Path	1.22	1.46	0.20	0.94	1.20	1.64	1.46	1.30	1.40	0.60	0.72	0.86	1.14	0.60	0.90	0.64	0.82	0.78	1.18

D = soil so unstable that it was impossible to study plot without causing damage to burrows; A = Plot 5 abandoned from breeding studies when tourist path was redirected through this plot

Table 3: Magdalena Island nest analysis - 2018/19

Plots	Nests	Eggs	Eggs Lost	Lost Hatching	Chicks Lost	Fledged	Fledged per Nest
1	10	20	10%	0%	10%	80%	1.60
2	14	28	14%	7%	36%	43%	0.86
3	12	24	42%	8%	33%	17%	0.34
4	10	20	30%	5%	40%	25%	0.50
5	-	-	-	-	-	-	-
6	12	24	38%	4%	33%	25%	0.50
7	11	22	9%	5%	50%	36%	0.72
Mean			**24%**	**5%**	**34%**	**37%**	**0.74**
PATH	17	34	32%	3%	6%	59%	1.18

*Plot 5 removed from breeding study in 2014 when tourist path was redirected through it.

Table 4: Cabo Virgenes nest analysis

Season	Lost as Eggs	Lost Hatching	Lost as Chicks	Fledged	Fledged per Nest	Chick Weight
2003/04	26%	2%	62%	10%	0.20	
2004/05	13%	2%	28%	57%	1.14	
2005/06	30%	5%	28%	37%	0.74	
2006/07	16%	1%	13%	70%	1.40	2.9 kg
2007/08	14%	3%	13%	70%	1.40	3.2 kg
2008/09	30%	9%	12%	49%	0.98	3.3 kg
2009/10	25%	4%	6%	65%	1.30	3.2 kg
2010/11	12%	2%	8%	78%	1.56	3.2 kg
2011/12	17%	2%	11%	70%	1.40	3.1 kg
2012/13	21%	2%	14%	63%	1.26	3.1 kg
2013/14	23%	10%	3%	64%	1.28	3.1 kg
2014/15	19%	4%	4%	73%	1.46	3.2 kg
2015/16	37%	8%	10%	45%	0.90	3.1 kg
2016/17	13%	3%	9%	75%	1.50	3.2 kg
2017/18	33%	3%	12%	52%	1.04	3.1 kg
2018/19	23%	7%	10%	60%	1.20	3.2 kg
2019/20	30%	3%	12%	55%	1.10	3.1 kg
MEAN	**24%**	**5%**	**9%**	**62%**	**1.24**	**3.15 kg**

plots located in areas with zero contact with tourists had the lowest breeding success (0.5 chicks per nest or less). The other study colony in Chile is Contramaestra Island. It is nearer to Tierra del Fuego and despite being just 18km. from Magdalena Island, it has more reliable rainfall. As a result Contramaestra Island did not suffer any drought and the population has remained entirely healthy. In 1990/91 the population stood at just 400 pairs, and this has since increased to 26,000 pairs in 2019/20. Some of the penguins forced to leave Magdalena Island over the years appear to have settled on neighbouring Contramaestra Island. Since Contramaestra Island has no tourism, no comparison was necessary.

Argentina: The Magellanic penguin population at Cabo Vírgenes has increased by 60% during the last 30 years, from 89,000 pairs in 1987/88 to 146,000 pairs in 2019/20 (Schiavini *et al.* 2005, Bingham 2020). With very few tourists visiting the colony there is no significant difference in breeding success between penguins alongside the tourist path and penguins well away from tourists. The colony at Cabo Virgenes appears to be in good health with high breeding success averaging well over 1 chick per nest (Table 4, Figure 4). Other colonies studied in southern Argentina are also stable or increasing, with 40,000 pairs at Monte Leon, 90,000 pairs on Isla Leones, 50,000 pairs at Punta Entrada, 35,000 pairs on Isla Cormoran, 10,000 pairs at Bahia Laura, 30,000 pairs at Punta Buque, 15,000 on Isla Pinguino and 30,000 pairs at Puerto Deseado. Only the northern colonies in the Provincia of Chubut appear to be in decline, as a result of commercial fishing and oil pollution caused by the deliberate discharge of ballast water by shipping.

Falkland Islands: Magellanic penguin populations on the Falkland Islands have declined by 92% from 1,300,000 pairs in 1989/90 to 100,000 pairs in 2018/19. Comparison shows that low breeding success in the Falkland Islands has failed to produce enough chicks to replace natural adult mortality (Fig 4). This decrease in chick survival in the Falkland Islands was due to increased levels of starvation and malnutrition. Fledgling weights averaged 3.2kg in Chile and Argentina, but only 2.7kg in the Falkland Islands, differing significantly at the 5% level using a Mann Whitney *U* test. Chicks in Chile and Argentina fledge in late January and early February, whilst in the Falkland Islands many chicks do not fledge until April. Many chicks are abandoned by their parents in April, and left to starve to death in the burrows still in their fluffy chick plumage, because the parents biological clock forces them to abandon the nest and prepare for their annual moult prior to the onset of winter. This has never been observed in any colony in Chile or southern Argentina, although it has occasionally been observed at Punta Tombo in Chubut.

Mean foraging duration during chick rearing averaged 34 hours in the Falklands, and 14 hours in Chile and Argentina, differing significantly at the 5% level using a Mann Whitney *U* test (Bingham 2002). Chicks with a fledging weight of only 2.7kg have very little body fat reserves, and lack sufficient energy reserves to survive for long after they leave the colony. Even healthy chicks weighing well over 3kg face high mortality as they learn to feed for themselves during their first few months at sea. Diet sample analysis shows that Magellanic penguins in the Falkland Islands rely on species of fish and squid that are commercially harvested by the Falkland Islands' commercial fishing industry (Table 5), especially loligo squid (*Loligo gahi*) and blue whiting (*Micromesistius australis*). These commercially harvested species make up 26.5% of the observed diet of Magellanic penguins, the highest overlap of any Falkland Islands penguin. Gentoo penguins make up only 5.9% of observed diet and Rockhopper penguins 10.2% of observed diet (Table 5). This observed level of competition with commercial fisheries is also an under-estimate. If there was no commercial fishing activity then the abundance of the penguin's favourite prey would be considerably higher. Since penguin diet analysis in the Falkland Islands only began in 1989, it has only ever been conducted under conditions of reduced prey abundance imposed by commercial fishing since 1988. The importance of such species to penguins is therefore inevitably under-estimated and the true dietary overlap will be much higher. Almost one fifth of the Magellanic penguin diet in the Falkland Islands is now made up of lobster krill (*Munida gregaria*), even though it is not digested by Magellanic penguin chicks and can be harmful (Thompson 1993). The chicks are fed so much lobster krill in the Falkland Islands that the guano outside the burrows is often pink. Diet sample studies of Magellanic penguins at Magdalena Island and Cabo Virgenes show a complete lack of lobster krill in their diet, even though lobster krill is present in great abundance, forming the principal diet of cormorants nesting alongside the penguins on Marta Island, Contramaestra Island and Magdalena Island.

DISCUSSION

Magellanic penguins are only found in Chile, Argentina and the Falkland Islands. In Chile and Argentina populations are stable and healthy, with increases in some colonies and declines at others. Populations in the Falkland Islands have declined by 92% since the establishment of the Falkland Islands Government's commercial fishing industry in 1988. Population studies are being carried out in all three countries using the same methodology of long-term fixed study plots. Historically Magellanic penguin population studies have been hampered by the use of inappropriate census techniques. Small colonies of Magellanic penguins can be counted nest by nest, but a direct count is impossible for large colonies. In such cases it is necessary to calculate the size of the population by plotting the total area of the colony, and multiplying this area by the density of nests per square meter determined by study plots.

According to the criterion given above and the errors inherent in the use of an average nesting density instead of direct counts, the population totals obtained using the aforementioned methodology have a margin of error of plus or minus 20%. There are several methods available to obtain a single population estimate of Magellanic penguins, but only direct counts of every nest can reduce this margin of error. If the objective is to monitor population changes, or compare two or more censuses separated by time, then fixed plots is the only method available for large colonies. Fixed plots allow the precision of direct counts in small areas located within the colony. The use of fixed plots has a margin of error comparable with any other methodology when estimating population size, but with the advantage that using fixed plots eliminates the margin of error when estimating *changes* in population. Even small population changes can be detected using fixed plots. Other methods of estimating Magellanic penguin populations re-introduce the margin of error with each new count, eliminating any possibility of detecting changes smaller than the combined margin of error of any two counts (40%). To explain this in layman's terms, imagine throwing grains of rice onto a large table. Time does not allow each grain to be counted, so instead small squares (study plots) placed randomly across the table can estimate the amount of grains on the table. The estimate will obviously have a large margin of error because it assumes that the density in the squares is representative of the whole table. If the squares are fixed then the same result will be recorded each time that the count is repeated. If someone later threw some additional grains onto the table, some additional grains would fall into the squares and the increase would be detected. If the squares were not fixed, or if other methodology was employed such as transects running across the table at random, then the count will be different each time it is repeated, even if the grains on the table have not changed. If the methodology gives different results each time it is repeated, then it is clearly inappropriate for detecting changes. Long-term population studies using fixed plots began in the Falkland Islands in 1989, in Chile in 1998, and in Argentina in 2003.

The decline of Magellanic penguins on Magdalena Island is worrying at a local level, but does not indicate a decline at a regional level. The decline is the result of micro-climatic factors around Magdalena Island that make rainfall unreliable, causing periodic droughts that have destroyed the natural vegetation. This appears to be unique to Magdalena Island with no other colony in the region suffering from

drought. Neighbouring Contramaestra Island has suffered no droughts and the penguin population there has increased from 400 pairs in 1990/91 to 26,000 pairs in 2019/20. The increase of 24,000 pairs at Cabo Vírgenes is also greater than the loss observed on Magdalena Island during the same period, and it is likely that Cabo Virgenes has also benefited from an influx of penguins leaving Magdalena Island. Adding the colonies in this region together indicates an increase of 4,000 pairs between 2008/09 and 2018/19, and an increase of 50,000 pairs since the 1990s, so the regional population as a whole is healthy and stable. At most of the colonies in Argentina the soil is not suitable for burrows, but the terrain is covered by thorn bushes which the penguins use as protection instead of burrows. There are no bushes at all on Magdalena Island, so without soil suitable for burrows the penguins are left exposed to predators and the weather, forcing them to look elsewhere to breed.

Magdalena Island, Contramaestra Island and Cabo Virgenes are all located in maritime areas that are protected from large-scale commercial fishing by no-fishing zones. Penguins at these sites can usually find plenty of food to feed their chicks, with the exception of during climatic events such as El Niño and La Niña. Penguin populations are tolerant of many problems if food remains abundant. Magellanic penguin populations on the Falkland Islands have declined by 92% from 1,300,000 pairs in 1989/90 to 100,000 pairs in 2019/20. This decline is due to competition for food resources with the commercial fishing industry. In September 2000 the participants of the Spheniscus Penguin Conservation Workshop held at La Serena (Chile) signed a petition calling on the Falkland Islands Government to establish no-fishing zones around penguin colonies, but that protection has still not been provided, and the penguin population continues to decline. Penguins on Magdalena Island have declined because of lack of rainfall that has led to a loss of the original vegetation. Until such time as the vegetation can stabilise the soil in these areas, the penguin population on Magdalena Island is likely to continue declining. However neighbouring colonies at Contramaestra Island and Cabo Virgenes have space for expansion if penguins do continue to abandon Magdalena Island. Data over the last 20 years indicate that tourism on Magdalena Island is not the cause of the decline, and even has a minor role in improving breeding success for penguins nesting alongside the tourist path. Penguins nesting in the presence of tourists have higher breeding success than other penguins on the island. The main predator of penguin chicks on Magdalena Island is the Skua (*Stercorarius chilensis*). The skua is very shy and avoids areas frequented by tourists. A reduction in the abundance of the skua decreases the mortality of chicks and increases the breeding success of the penguins. The data for Magdalena Island indicate that penguins raise more chicks and suffer less mortality of eggs and chicks in the presence of tourists, because the presence of tourists reduces the level of predation by skuas. Similar findings were recorded in Argentina and the Falkland Islands.

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