Earth & Environmental Science 2019 v1.4

IA3 high-level annotated sample response

March 2024

Research investigation (20%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

The sample is an unedited authentic student response produced with permission. Any identifying features have been redacted from the response. It may contain errors and/or omissions that do not affect its overall match to the characteristics indicated.

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

2. apply understanding of the cause and impact of Earth hazards or global climate change to develop research questions
3. analyse research evidence about the cause and impact of Earth hazards or global climate change
4. interpret research evidence about the cause and impact of Earth hazards or global climate change
5. investigate phenomena associated with the cause and impact of Earth hazards or global climate change through research
6. evaluate research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change
7. communicate understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change.

Note: Objective 1 is not assessed in this instrument.

Instrument-specific marking guide (ISMG)

Criterion: Research and planning

Assessment objectives

3. analyse research evidence about the cause and impact of Earth hazards or global climate change
4. interpret research evidence about the cause and impact of Earth hazards or global climate change

The student work has the following characteristics:	Marks
• informed application of understanding of the cause and impact of Earth hazards or global climate change demonstrated by a considered rationale identifying clear development of the research question from the claim • effective and efficient investigation of phenomena associated with the cause and impact of Earth hazards and global climate change demonstrated by – a specific and relevant research question – selection of sufficient and relevant sources.	5–6
• adequate application of understanding of the cause and impact of Earth hazards or global climate change demonstrated by a reasonable rationale that links the research question and the claim • effective investigation of phenomena associated the cause and impact of Earth hazards and global climate change demonstrated by – a relevant research question – selection of relevant sources.	3–4
• rudimentary application of the cause and impact of Earth hazards or global climate change demonstrated by a vague or irrelevant rationale for the investigation • ineffective investigation of phenomena associated with the cause and impact of Earth hazards and global climate change demonstrated by – an inappropriate research question – selection of insufficient and irrelevant sources.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis and interpretation

Assessment objectives

4. interpret research evidence about the cause and impact of Earth hazards and global climate change

6. evaluate research processes, claims and conclusions about the cause and impact of Earth hazards and global climate change

The student work has the following characteristics:	Marks
• systematic and effective analysis of qualitative data and/or quantitative data within the sources about the cause and impact of Earth hazards or global climate change demonstrated by – the identification of sufficient and relevant evidence – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of limitations of evidence • insightful interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by justified scientific argument/s.	5–6
• effective analysis of qualitative data and/or quantitative data within the sources about the cause and impact of Earth hazards or global climate change demonstrated by – the identification of relevant evidence – identification of obvious trends, patterns or relationships – basic identification of limitations of evidence • adequate interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by reasonable scientific argument/s.	3–4
• rudimentary analysis of qualitative data and/or quantitative data within the sources about the cause and impact of Earth hazards or global climate change demonstrated by – the identification of insufficient and irrelevant evidence – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of limitations of evidence • invalid interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by inappropriate or irrelevant argument/s.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Conclusion and evaluation

Assessment objectives

7. communicate understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change

The student work has the following characteristics:	Marks
• insightful interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by justified conclusion/s linked to the research question • critical evaluation of the research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – insightful discussion of the quality of evidence – extrapolation of credible findings of the research to the claim – suggested improvements and extensions to the investigation that are considered and relevant to the claim.	5–6
• adequate interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of the research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – reasonable description of the quality of evidence – application of relevant findings of the research to the claim – suggested improvements and extensions to the investigation that are relevant to the claim.	3–4
• invalid interpretation of research evidence about the cause and impact of Earth hazards or global climate change demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of the research processes, claims and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – cursory or simplistic statements about the quality of evidence – application of insufficient or inappropriate findings of the research to the claim – ineffective or irrelevant suggestions	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objectives

The student work has the following characteristics:	Marks
• effective communication of understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgement of sources of information through appropriate use of referencing conventions	2
• adequate communication of understandings and research findings, arguments and conclusions about the cause and impact of Earth hazards or global climate change demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions	1
• does not satisfy any of the descriptors above.	0

Context

Investigate the following claim:

- prolonged El Nino events cause the extinction of vulnerable species.

You may identify an alternative claim in consultation with your teacher. This claim must be related to Unit 4 subject matter.

Task

Gather secondary evidence related to a research question in order to evaluate the claim. Develop your research question based on a number of possible claims provided by your teacher.

Obtain evidence by researching scientifically credible sources, such as scientific journals, books by well credentialed scientists, and websites of governments, universities, independent research bodies or science and technology manufacturers. You must adhere to research conventions.

See IA3 sample assessment instrument: research investigation 20% (available on the QCAA Portal).

Sample response

Criterion	Marks allocated	Provisional marks
Research and planning Assessment objectives 2, 5	6	6
Analysis and interpretation Assessment objectives 3, 4	6	6
Conclusion and evaluation Assessment objectives 4, 6	6	6
Communication Assessment objective 7	2	2
Total	**20**	**20**

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

CLAIM

Prolonged El Nino events cause the extinction of vulnerable species.

RATIONALE

The Galapagos Penguin (*Spheniscus mendiculus*) is a small equatorial penguin endemic to the Galapagos islands. Recent years have seen the population fluctuate severely and it is now listed as endangered (World Wildlife Foundation, 2021). Already impacted by fishing, habitat disturbance, invasive species and disease, the environmental effects associated with El Niño are considered a major threat to the Galapagos Penguin. (Galapagos Conservation Trust, 2020). As a highly vulnerable species, it becomes increasingly important to understand and attempt to address the threats facing these organisms as El Niño events become more frequent and severe with climate change (Cai, 2014). Of all the penguin species, only the Galapagos penguin lives on the equator and is able to do so because of the cold oceanic upwelling of the equatorial undercurrent. As it hits the western edge of the Galapagos archipelago, cold, nutrient-rich water rises to the surface (Chavez, 1991), and provide nutrients for phytoplankton growth (MILLS, 1999).
The El Niño-Southern Oscillation (ENSO) cycle occurs when sea surface temperatures (SST) in the east Pacific Ocean warm, causing a shift in atmospheric circulation (BOM, 2014). El Niño has a damaging effect on marine life off the Pacific coast as upwelling weakens and without the nutrients, there is less phytoplankton. This reduces the number of small fish, the main food source of the penguin (NOAA, 2020).
A research question was developed from the claim. El Niño affects the Galapagos archipelago (Karnauskas, 2015) positioned in the warming Pacific Ocean. Due to a weakening of the trade winds and reduced upwelling of the equatorial undercurrent, the Galapagos Islands suffer the effects of an El Niño intensely. As a result, it was determined that this region be an area of focus when considering the effects of El Niño. Considering the term ‘prolonged’, ENSO events may be classed as prolonged if they become more frequent, severe or last for longer periods. To determine a species at risk of extinction, the vulnerable Galapagos Penguin (*S.mendiculus*) is likely to be at risk of increased ENSO events (Education National Geographic, n.d.), and so the following research question was developed:

How do prolonged El Niño events in the Pacific Ocean, measured using sea surface temperature (SST), negatively impact the population of Galapagos penguins (*S.mendiculus*) and increase their risk of extinction?

Research and planning [5–6]

a considered rationale identifying clear development of the research question from the claim

The rationale communicates the sequence of scientific ideas or events involved in the development of the research question from the claim.

Research and planning [5–6]

selection of sufficient and relevant sources

Sources throughout the response are scientific and provide enough evidence for the development of a scientific argument that responds to the research question.

Research and planning [5–6]

a specific and relevant research question

The research question has been developed from the claim and is connected to the topics covered in the unit.

ANALYSIS AND INTERPRETATION

Evidence 1

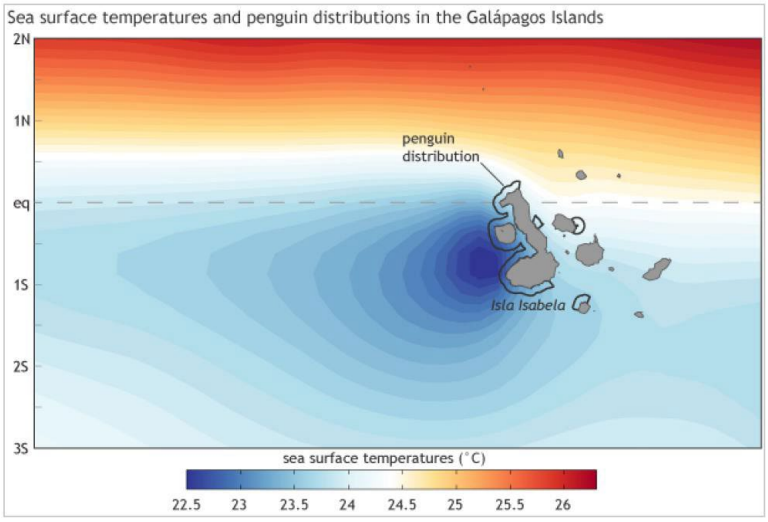

Figure 1: Annual mean SST from 1982 to 2014 and distribution of Galapagos penguins (black lines). (Karnauskas, 2015)

Analysis and interpretation [5–6]

identification of sufficient and relevant evidence

The evidence is appropriate for the purpose of responding to the research question. It is applicable and directly connected to the formation of the scientific argument

Karnauskas et al (2015) presented a study on the effects of El Niño on the Galapagos islands. The data shows average SST between 1982-2014. Figure 1 shows that the SST to the west of the Galapagos islands is significantly colder at 22.5ºC than the east side at 24ºC, matching the upwelling of the colder undercurrent. North of the islands, the water is warmer at 24.5ºC and increasing to 25.5ºC at 1ºN. Most of the Galapagos archipelago lies south of the equator. Approximately 95% of the Galapagos penguin population is distributed along the cooler west coast. This is due to the large quantity of nutrients that travel to the surface by topographical upwelling of the Equatorial Undercurrent (NOAA, 2020). Penguin distribution closely coincides with the main upwelling area.

Analysis and interpretation [5–6]

thorough identification of relevant trends, patterns or relationships

Identified relationships are applicable and directly connected to the formation of the scientific argument.

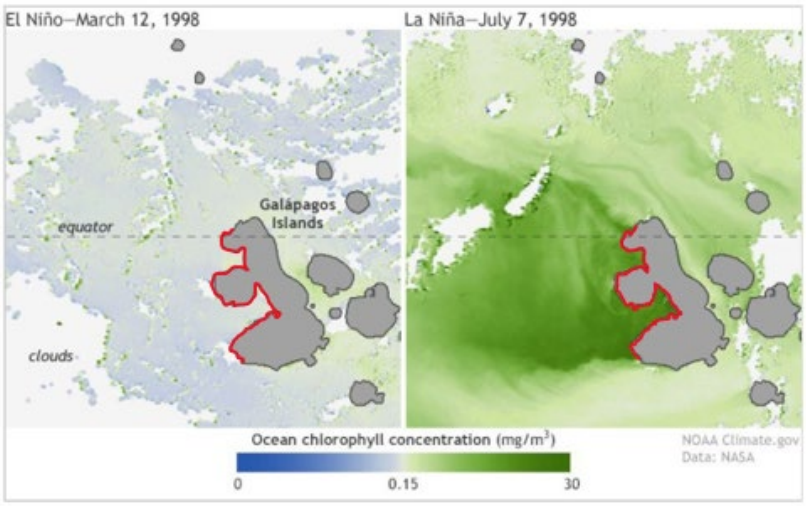

Figure 2: Satellite image of ocean chlorophyll around the Galapagos Islands (Boersma, 2013)

Analysis and interpretation [5–6]

identification of sufficient and relevant evidence

The evidence is adequate for the purpose of responding to the research question and can support a valid conclusion.

Analysis and interpretation [5–6]

thorough identification of relevant trends, patterns or relationships

The response identifies trends, patterns of relationships that are not superficial or partial. The trends, patterns, or relationships have direct bearing upon and are applicable to the formation of the scientific argument

Analysis and interpretation [5–6]

identification of sufficient and relevant evidence

The evidence draws upon all available data to respond to the research question. It links directly to the research question.

Analysis and interpretation [5–6]

thorough identification of relevant trends, patterns or relationships

Figure 2 shows the main distribution of the Galapagos penguin (red), and a satellite image of chlorophyll concentrations (found in phytoplankton) around the Galápagos during an El Niño and a La Niña event in 1998.

Phytoplankton is the food source for fish, which is prey to the penguins. On March 12, there is an average chlorophyll level of below 0.15mg/m^3 with some areas slightly higher. The area around the penguin habitat is very low in chlorophyll at 0.1mg/m^3. During la Niña, the chlorophyll levels are 30mg/m^3 around the penguin habitats of the western side of the main island, this is 199 times more phytoplankton. These high levels justify the location of the penguin habitat, with cold, nutrient-rich waters providing their food source. The concentrated chlorophyll matches the upwelling undercurrent. This evidence shows that the penguins rely on the cold, upwelling current to provide prey and during an ENSO event, the waters are depleted of nutrients, leading to a decrease in their food source.

EVIDENCE 2

Sea surface temperature (SST) is a reliable indicator of ENSO events (National Oceanic and Atmospheric Administration, 2021). Therefore, SST will be used to indicate El Niño years.

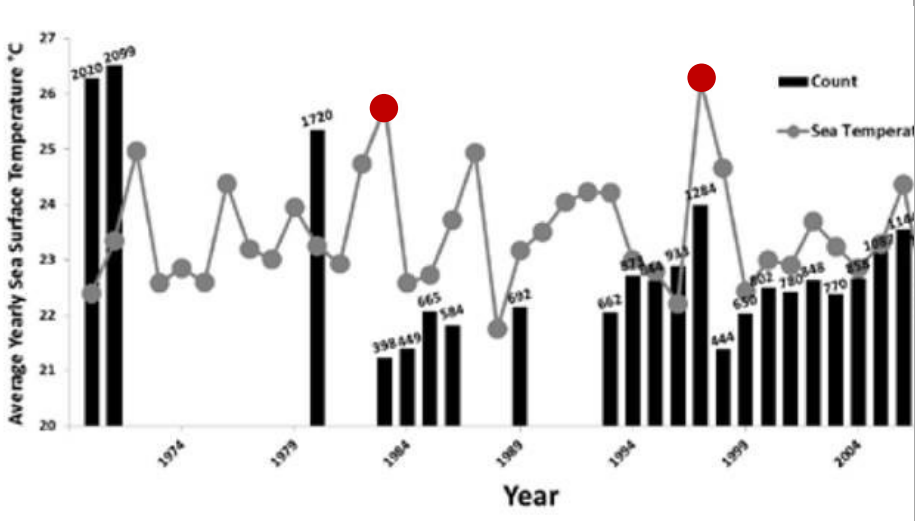

Figure 3: The population of *S.mendiculus* and average annual ST between 1970-2009 (Vargas, 2006)

Boersma et al. (2013) investigated the population estimate of Galapagos penguins between 1970-2009. The circles represent the average annual SST, measured at Santa Cruz, Galapagos. The strongest ENSO events, 1982-83 and 1997-98 (Storlazzi, 2000), are indicated in red. Periods of high SST are followed by falls in the penguin population, this can be seen in 1972, 1982 and 1997 (ENSO events). Following the ENSO event of 1982, the population fell to 398 penguins, loss of 77%, and during 1997 it fell to 444, a loss of 66%. Both of these ENSO events reduced the population to its lowest levels. A pattern can be observed that population declines are followed by small recoveries in population size over subsequent years, but by 2009 the population was still only 50% of its level before the 1972 ENSO event. A limitation is that between

Analysis and interpretation [5–6]

thorough and appropriate identification of limitations of evidence

The response identifies limitations of evidence that affect how well it can be used to develop a response to the research question.

Analysis and interpretation [5–6]

justified scientific argument/s

The interpretation of the evidence shows an understanding of the process used to select evidence to construct a scientific argument. The scientific argument communicates sound reasoning and draws upon valid and reliable evidence.

1970-1993, the annual recording of populations was inconsistent until 1993 where population was recorded annually. During ENSO events, less nutrients leads to a limited food supply. Penguins reduce mating as they are less likely to survive if they invest energy or devote their food to young (Smithsonian Ocean, 2021). This evidence supports a significant decrease in penguin population after periods of increased SST.

EVIDENCE 3

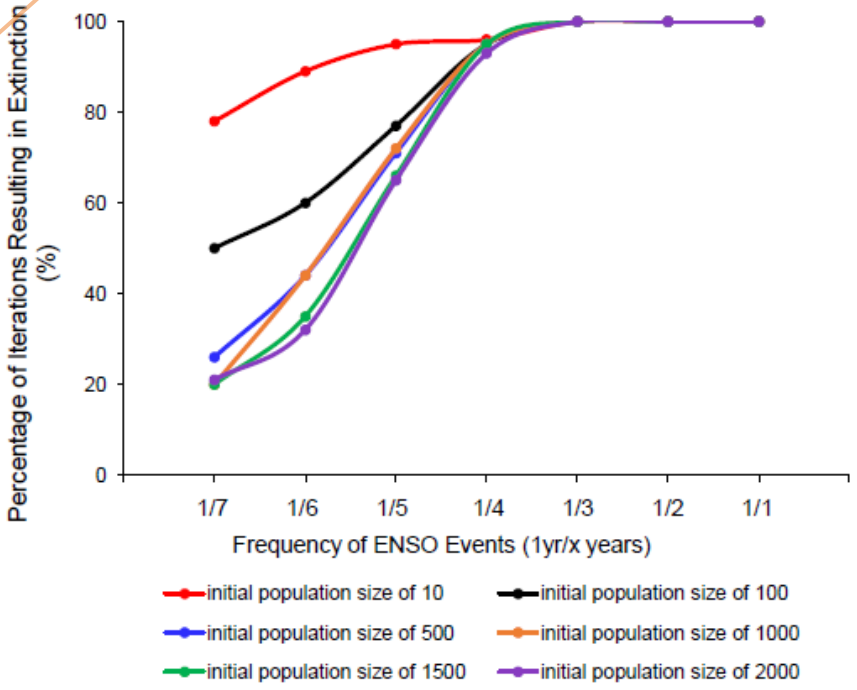

Figure 4: The probability of an extinction event against the frequency of ENSO events (Clare, 2016)

Analysis and interpretation [5–6]

identification of sufficient and relevant evidence

The evidence draws upon all available data to respond to the research question. It links directly to the research question.

Analysis and interpretation [5–6]

justified scientific argument/s

The scientific argument uses a process of sound reasoning and draws upon valid and reliable evidence.

Clare (2016) used a model to predict extinction risk for initial population sizes against ENSO frequency, within 100 years. For all population sizes with ENSO frequency occurring every 1-3 years, the probability of extinction is 100%. The lower the initial population size, the greater the risk of extinction. Using an estimated current population of 2000 (Galapagos Conservation Trust, 2019) and with ENSO events occurring every 2-7 years (NOAA, 2020), the risk of extinction is estimated at 20% if ENSO occurs every 7 years and 100% if it occurs every 2 years. If another ENSO event occurs before the population has chance to recover, the risk of extinction becomes more, this is significant if the population reduces to 100 or less. An intense single event or a prolonged event could likely drive the species to extinction, particularly without time to recover between events. This evidence shows a high likelihood of penguin extinction with increased frequency or severity of ENSO events.

LIMITATIONS OF EVIDENCE

Analysis and interpretation [5–6]

thorough and appropriate identification of limitations of evidence

The response identifies limitations of the evidence that are not superficial or partial. The limitations are suitable for determining the reliability of the evidence in responding to the research question

Figure 1 has a large scale that doesn't show exact temperatures near penguin habitats. Vague identification of penguin colonies impacts the reliability in determining a relationship. Figure 2 shows interference in the data, the clouds are blocking visibility, preventing data collection. The data is measured in 1998, more recent data and data over a number of years would improve validity. Figure 3 has some absent years for population data resulting in a difficulty in observing trends after 1972 or before 1982 ENSO events. The time frame which the data was collected ends in 2009, more recent data would allow a more current analysis of the situation and opportunity to see the effect of recent ENSO events. In figure 4, the model shows probability of extinction for only 6 initial populations, a more comprehensive study of populations would enable more valid conclusions.

QUALITY OF EVIDENCE

Conclusion and evaluation [5–6]

insightful discussion of the quality of evidence

The discussion shows understanding of the features of the evidence that affect its ability to be used to respond to the research question.

All evidence was obtained from peer-reviewed academic papers, ensuring reliability. Figure 1 included data for 1982-2014, ensuring reliable trends. The map was large, a smaller scale would improve precision. Figure 2 was limited to 1998, lacking validity in long-term chlorophyll trends. For Figure 3, during ENSO events, penguin counting is problematic with penguins spending more time at sea (Vargas, 2007). The population count varies depending on breeding, time of day, weather, and availability of prey. As the data was measured over many years it will be difficult to ensure the same methods of counting, and this did vary with mark-recapture used before 1996 and observations after 1996 (Vargas et al.,2005). This makes the population data somewhat unreliable with uncertainty in the values despite a good methodology. Other factors may have affected penguin populations besides SST; disease, parasites and introduced species may contributed to a decline in numbers (Levin et al., 2009, Vargas et al., 2007).

Figure 4 used a model, which have uncertainties associated with them. The model ensures that other factors remain constant and only ENSO events affect the population. The model assumed that all adults were breeding adults in an equal sex ratio. As penguins only breed from age three and less than 60% of females breed (Vargas, 2007) this will affect the model's prediction. To improve this model, modelling software that accounts for age and fecundity is recommended.

The limitations in figure 1 and 2 are minimal and have a low impact on the quality of scientific argument. However, the limitations identified for figure 3 and 4 are moderate and have a significant impact on the quality of the argument. This reduces the confidence in drawing conclusions regarding the claim.

Communication [5–6]

appropriate use of genre conventions

The use of headings and paragraphs fits the purpose of a research investigation.

Conclusion and evaluation [5–6]

justified conclusion/s linked to the research question

The response uses sound reasoning and valid and reliable evidence to support conclusions that directly respond to the research question.

Conclusion and evaluation [5–6]

extrapolation of credible findings of the research to the claim

The response uses the conclusion to the research question to support or refute the claim within the limitations of the evidence identified in the analysis.

Conclusion and evaluation [5–6]

suggested improvements and extensions to the investigation that are considered and relevant to the claim

The improvements address the limitations associated with the evidence. The extensions identify modifications that would complement the findings of the investigation and have the potential to provide new evidence that could be used to evaluate the claim further.

CONCLUSION

The evidence allows the research question to be answered. Evidence shows that penguin habitat on the western coast on the Galapagos Islands is due to the cold, upwelling current that provide nutrients for phytoplankton. During El Niño, nutrients are depleted, evidenced by 199 times less chlorophyll figure 2). Figure 3 justifies a significant decreases in the population of *S.mendicus* after years of increased SST (ENSO indicator) particularly 1982-83 and 1997-98 where the population . Finally, the chance of extinction was modelled, and the current population has a 20% probability if El Niño occurs every 7 years and 100% probability if it increases to every 2 years. Whilst recognizing the limitations, the evidence stills shows the damaging effect of ENSO events on the population of *S.mendicus* and a high likelihood of extinction with increased frequency or prolonged ENSO events.

When extrapolating the evidence to the claim that prolonged El Niño's can cause extinction of species, the evidence does show support for the claim. El Niño events are catastrophic for populations of *S.mendicus* and given the increased frequency of ENSO events and the rise in SST, extinction has a high likelihood without intervention. This conclusion is limited however, in that other factors may have affected the population decline and the model used to predict extinction does not consider all breeding factors. To fully support the claim, further research into contributing factors such as disease and introduced species needs to be conducted to ensure that El Niño is the determining factor, and an improved model that more accurately predicts risk is necessary in order to provide more convincing support for the claim.

IMPROVEMENTS

From the limitations presented, the following improvements are suggested:

- Using a finer scale will show more precise SST for the ocean around the Galapagos islands and allow temperature variations to be more accurately discussed.
- Data for chlorophyll abundance be collected on an annual basis to allow productivity to be observed over a range of years rather than for a single year.
- Measuring penguin populations annually to have a complete record of population trends and obtaining data beyond 2009 would allow more recent population trends to be observed, in particular the ENSO event of 2015-16 that greatly affected the population (El Niño: Pacific Wind and Current Changes Bring Warm, Wild Weather, 2021)
- use modelling software to predict extinction that accounts for age and fecundity to ensure a more accurate extinction risk.
- Using technology to accurately count penguins will improve reliability. Software that uses aerial photography is

recommended with a correction factor for those at sea feeding and in hides (Australian Antarctic program, 2001).

Communication [2]

fluent and concise use of scientific language and representations

The response is easily understood and avoids unnecessary repetition.

EXTENSIONS

To further support the claim, the following extensions are recommended:

- research the effect of El Niño on other vulnerable Galapagos species such as the marine iguana.
- Other contributing factors (besides ENSO) could be investigated to observe their effects on penguin population, such as disease, introduced species, and human impacts. This would determine the contributing factors affecting the population.
- Develop modelling software for single prolonged ENSO in addition to increased frequency could compare the effects of both scenarios on penguin population.

Word Count: 1996 excluding all referencing

Communication [2]

acknowledgement of sources of information through appropriate use of referencing conventions

The sources of information are acknowledged using a referencing style that is suitable for the purpose of the essay.

REFERENCES

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Appendix 1

El Nino years (across 2 years)	El Nino years (ending year = greater impact observed)
1963-1964	1964
1965-1966	1966
1969-1970	1970
1972-1973	1973
1977-1978	1978
1982-1983	1983
1987-1988	1988
1991-1992	1992
1993-1994	1994
1994-1995	1995
1997-1998	1998
2002-2003	2003
2006-2007	2007
2009-2010	2010
2015-2016	2016
DATA FROM: http://www.bom.gov.au/climate/enso/enlist/	