様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　２ 年　 ６ 月 １５ 日現在

機関番号：６２６１１
研究種目：若手研究
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研究課題名（和文）Penguins as ocean sentinels: using video loggers attached on predators to understand the ecological niche of jellyfishes in Antarctica

研究課題名（英文）Penguins as ocean sentinels: using video loggers attached on predators to understand the ecological niche of jellyfishes in Antarctica

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研究成果の概要（和文）：本研究は、南極域においてペンギンなどの高次捕食動物がクラゲを食べる行動を定量的に把握し、クラゲ捕食の理由を調べるために実施した。世界7カ国の研究者と共同で、12箇所のアデリーペンギン繁殖地で、親鳥へのビデオ記録計の装着を２年間実施した。その結果、アデリーペンギンや他の捕食動物が、従来考えられていたよりも高頻度でクラゲを捕食することが明らかになった。クラゲ捕食のために必要な潜水エネルギーコストは、獲得されるエネルギーよりも大きいと推定され、クラゲ捕食の理由はエネルギー獲得以外にあることが示唆された。体内で不足する栄養素を補給している可能性や、クラゲの生化学的組成の調査の必要性が示唆された。

研究成果の学術的意義や社会的意義
From this successful project we now know that jellyfishes are widely eaten by marine predators, but probably not for energy purposes. This is important for ecologists, to examine the flow of energy and matter in marine ecosystems; but this research may also change the way the public sees jellyfish.

研究成果の概要（英文）：This project brought together scientists from 7 countries, working at 12 locations around Antarctica. We used video loggers to examine jellyfish ingestions by Adelie penguins, during 2 years instead of 1 as initially planned.
We have found that penguins and other predators commonly eat jellyfishes, but probably not for energetic reasons (2020 published paper). This is especially the case for penguins repeatedly feeding on the same jellyfish, because of the cost to commute from the sea surface (paper in preparation).
Targeting jellyfish seems independent from local availability of the main prey (krill) and from regional climatic changes (analyses in progress). Hence, penguins seem to select to eat jellyfishes, but not consistently. Alternate hypotheses including self-medication are plausible. Examining which jellyfish biochemical components may be of interest to predators, and viewing jellyfish as functional food, may be important to better understand the oceans' ecology.

研究分野：Ecology

キーワード：Predator-prey　Jellyfish　Penguin　Bio-logging　Video　Antarctica

様　式　C－１９、F－１９－１、Z－１９（共通）

１．研究開始当初の背景 (Background)

Studying interactions between organisms is key to understand how ecosystem functioning may be impacted by environmental changes. Notably, prey selection by predators may indicate a shift in the available prey in the environment.

In Antarctica, environmental changes may lead penguins to feed on low-energy prey such as gelatinous zooplankton (salps, jellyfish), which may be favored by climatic perturbations [1,2]. Video loggers showed that Antarctic penguins may indeed eat jellyfish [3], but it is unknown whether this reflects low levels of the main prey's local availability.

２．研究の目的 (Purpose)

The objective of this research was to develop the use video data loggers at a large scale for the first time, to examine prey selection in Adélie penguins between Antarctic regions. From these data, the purpose was to infer whether or not the consumption of jellyfishes depends on the lack of the main prey (krill), related to regional climatic trends.

This project aimed at testing the hypothesis that predators with high energy demands (such as penguins) incorporating energy-poor prey to their diet would reflect an ecosystem perturbation which affected the production of high-quality prey. The alternate hypothesis was that low-quality prey such as jellyfishes may constitute valuable food items for reasons other than energetic, and hence would be consumed regardless of the main prey's availability.

３．研究の方法 (Method)

This project relies on the bio-indication approach: reflecting an ecosystem's conditions from the response of predators exploiting it. State-of-the-art video loggers were attached to Adélie penguins to reflect underwater prey ingestions.

Importantly, the ambitious aspect of this research was to study a predator species throughout its distribution range. Thanks to the involvement of an international network of scientists working on Adélie penguins from several locations around Antarctica, it was possible to examine prey ingestion of penguins according to a gradient of environmental conditions.

４．研究成果 (Research results)

The international network developed in this project performed better than expected. Instead of the 6 sites that were targeted over one year, penguins were studied over a total of 12 sites over two years. This is because video loggers could be recycled more than expected, and because the project appealed to more teams than anticipated (Figure 1).

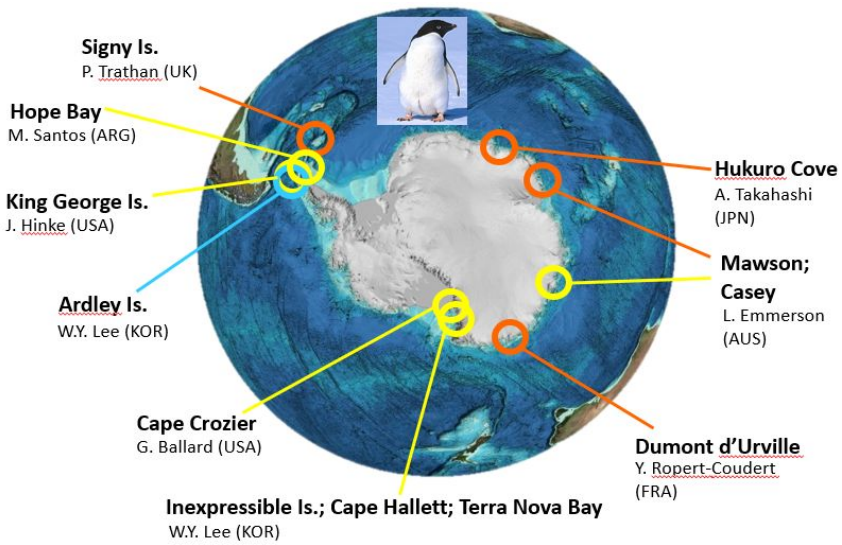

Figure 1: Map of the Antarctic showing the circumpolar video data collection achieved in this project: sampling: 5 sites from 5 countries were sampled in 2017-2018 (blue), and 11 sites from 7 countries in 2018-2019 (yellow); sites sampled in both years are shown in orange.

One consequence of this overwhelming success was the amount of footage available to analyze (>180 individual penguins with ~5 hours each), which is talking much longer than expected. Hereafter are presented preliminary results based on the analyses still in progress.

Following the initial plan of the project, the main outcome from the first year was achieved while the data were being collected. It was to examine cases of jellyfish captures by endothermic animals (seabirds, marine mammals, endothermic fishes) to elaborate the arguments for or against the energetic purpose of jellyfish captures by these predators.

In this first step of the project (published paper [4]), I used thermodynamic estimates showing that penguins barely have any energetic estimate from ingesting jellyfishes, because of their high content in water. In temperate waters (14°C), the costs are expected to match the gain, but in Antarctic waters the energetic balance is negative, because of the high cost to heat up the prey from the environment (0°C) to the penguins' body temperature (38°C, Figure 2).

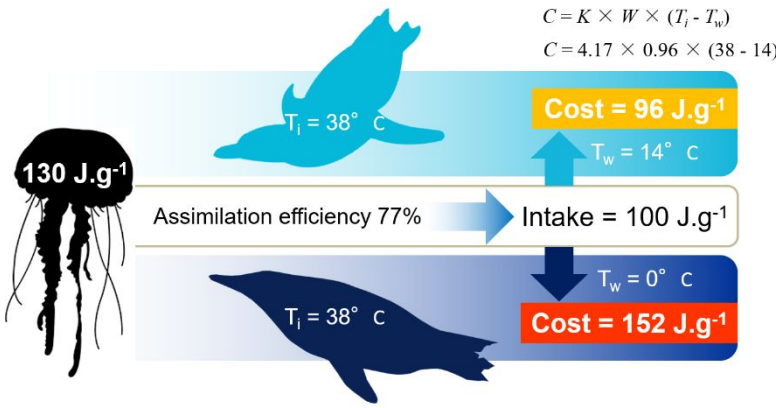

Figure 2: Energy balance of jellyfish captures for penguins, from thermo-dynamic equations. The energy of jellyfish tissue (130 J. g^{-1}), penguins may provide 100 J. g^{-1} to penguins, but with a cost of 96 J. g^{-1} in temperate waters (upper panel) and 152 in Antarctic waters (lower panel).

This research showed that the widespread captures of jellyfish by warm-blooded predators are not well explained in an energetic framework, unless the predators target exclusively the energy-rich parts such as gonads, which are not always present in the jellyfish captures seen in the videos. Biochemical research suggests that non-energetic food such as jellyfishes may contain bio-active components that would benefit to the consumer facing homeostatic challenges (parasitism, thermoregulation, alertness). Such hypothesis remains to be tested.

Further, the videos collected in this project allowed to confirm that Adélie penguins could dive repeatedly to exploit the same jellyfish over extended durations, despite (1) the additional energetic cost associated with diving and returning to the surface for breathing, and (2) the local abundance of krill. Such examples of focal feeding on jellyfish (Figure 3), further indicates that feeding on jellyfish may not take place in an energetic context, and may not constitute a response to a low-quality feeding environment (paper in preparation).

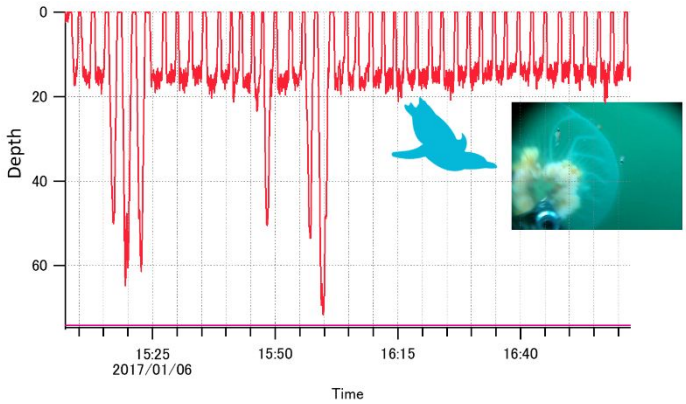

Figure 3: Diving activity of a penguin along time. The studied penguin dived repeatedly to the same depth, during more than 2 hours, to eat parts of the same jellyfish, as confirmed from the video records. Example from the dataset collected at Hukuro Cove, in Lutzow-Holm Bay.

On a large scale, videos suggest that penguins eat jellyfishes across regions, whether or not this region was undergoing significant warming and functional changes in the food webs, and even when krill was locally abundant. These analyses are still in progress, thus this large-scale study needs final quantifications to become a solid paper. However, the main hypothesis tested in this project ("jellyfish captures by penguins reflect a regional ecosystemic perturbation") seems largely unsupported, while a non-energetic framework remains valid.

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２．論文標題 Vaccination protects endangered albatross chicks against avian cholera	５．発行年 2018年
３．雑誌名 Conservation Letters	６．最初と最後の頁 e12443
掲載論文のDOI（デジタルオブジェクト識別子） https://doi.org/10.1111/conl.12443	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

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２．論文標題 Albatross chicks reveal interactions of adults with artisanal longline fisheries within a short range	５．発行年 2018年
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〔図書〕　計0件

〔産業財産権〕

〔その他〕
Prize & Awards:
Runner-up for the attendees’ vote Best Oral Presentation, 46th Meeting of the Pacific Seabird Group (27 February – 2 March, Lihue, USA).

６．研究組織

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