MIT2024-05 Testing the utility of visual deterrent options to mitigate incidental bycatch of protected species in set nets NOF-BIO-649

Preliminary results on the effect of Green LED lights on the behaviour of little penguins

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Executive summary

Set net fisheries in New Zealand pose a bycatch risk to protected seabirds, including penguin species whose coastal distributions overlap with fishing effort. Visual deterrents such as light-emitting diodes (LEDs) have shown potential to reduce bycatch in gillnet fisheries internationally, but their effects on seabirds in a New Zealand context, including the risk of attraction, remain uncertain.

This study tested the behavioural responses of little penguins (*Eudyptula minor*) to green LED lights in a non-fishing setting as a precursor to operational fishing trials. Trials were conducted in Oamaru Harbour, where penguins regularly transit between the marine environment and nesting sites. A grid fitted with commercially available green FishTek Marine NetLights was deployed across a known transit corridor, with trials alternating between illuminated and unilluminated conditions. Penguin movements and behaviour were recorded from shore during nocturnal transits.

Across nine trials conducted in October 2025, 168 observations of penguin movement in the vicinity of the experimental array were recorded; with 158 assumed to have occurred with the array and green LED lights being within the effective field of view of those penguins. Penguins swam through the grid on five occasions when no green LEDs were illuminated, whereas no penguins passed through the grid when LEDs were illuminated. Two observations involved penguins stopping briefly and altering their swimming direction when the grid was illuminated with green LEDs. No penguins were observed moving directly towards, circling, or interacting in any other way with the illuminated grid with green LED lights, i.e., there was no evidence of attraction to the green LED lights. Results from this study have provided evidence to inform fisheries management decisions regarding the potential adoption of LED-based mitigation, while highlighting the need for species- and context-specific evaluation before broader implementation.

1   Background

Set net fisheries in New Zealand pose a threat to protected species of seabirds and marine mammals that become entangled in them. This includes several penguin species, the endangered yellow-eyed-penguin, hoiho (*Megadyptes antipodes*), among them, whose range overlaps with set net fisheries targeting primarily elasmobranchs (school shark, rig, and elephant fish) along the east and southern coastlines of the South Island (Beentjes and Bian, 2022).

The use of light to elicit avoidance behaviour of bycatch species has gained considerable traction with an increasing number of studies completed across a range of different fishing gear types (Yochum et al. 2024). In their review, Yochum et al. (2024) cited 13 studies carried out since 2010 where lights were used in gillnet (both set nets and drift nets) and trammel fisheries. In a small number of these studies, the effectiveness for reducing seabird bycatch (e.g., cormorants and sea ducks) was considered (Ortiz et al., 2016; Mangel et al., 2018; Field et al., 2019; Bielli et al., 2020) with some configurations showing promise. However, their effectiveness in a New Zealand context is unknown, including the potential for unintended consequences such as attraction of protected species.

The Department of Conservation's (DOC) Conservation Services Programme (CSP) led MIT2024-05 "Testing the utility of visual deterrent options to mitigate incidental bycatch of protected species in set nets", as part of the CSP Annual Plan 2024. The project aimed to test the effectiveness of green Light-Emitting Diodes (LEDs) and Looming eye buoys as visual deterrents for protected seabird species below and above water respectively, in a non-fishing context. This project was planned as a precursor to a project contracted by Fisheries New Zealand (FNZ) to test the effect of LEDs on target fish species in setnet fisheries on the east coast of the South Island (PRO2024-03 "Trialling LED mitigation in setnet fisheries to assess effect on target fish species catch and protected species bycatch").

DOC and FNZ agreed to stage the projects, with MIT2024-05 completed in a non-fishing context prior to PRO2024-03 trials in a fishing context. This approach allowed potential unintended effects (e.g., attraction) of green LEDs to be assessed in a New Zealand setting before operational deployment, while improving efficiency through shared mitigation technology and coordinated trial design. To simplify the fieldwork and prioritize penguin deterrent, the LED component of MIT2024-05 was addressed first. The core objective of this project was to assess the effectiveness of green LEDs as a visual deterrent for diving seabirds (e.g., penguins, shags) in New Zealand waters.

2   Methods

2.1   Experimental Design: Location and species.

Following discussions with penguin experts, iwi, and the Otago Regional Council Harbourmaster, DOC selected a site within Oamaru Harbour where little penguins (*Eudyptula minor*) regularly move between the marine environment and their burrows. A range of alternative locations and experimental set-ups were considered during planning, including open-water foraging grounds and known breeding colonies of both hoiho and little penguins, with site selection guided by accessibility, feasibility of camera and observer deployment, and expected encounter rates. Deployments on feeding grounds were discounted due to the low likelihood of sufficient encounters within the available timeframe and resources. The selected colony at Oamaru comprises approximately 300 pairs, with most individuals returning to shore via the open ocean (www.penguins.co.nz). However, a subset of approximately 30 penguin pairs uses a sheltered, narrow corridor within the harbour (Philippa Agnew, Oamaru Penguins, pers. comm.), providing a consistent and observable transit pathway suitable for behavioural observations.

2.2   Experimental Design: LED lights and grid.

Green LED lights were supplied by DOC and consisted of commercially available FishTek Marine NetLights (Figure 1; Fishtek Marine Limited, UK), designed specifically for deployment on static fishing gear such as set nets and gillnets. The lights emit green light with a peak wavelength of approximately 520 nm, which is within the visible spectrum of many marine vertebrates, including seabirds and marine mammals. NetLights are compact, pressure-rated, and battery-powered, allowing autonomous operation over extended deployment periods (over 500 hours, www.fishtekmarine.com). Green wavelengths were selected based on previous international studies suggesting potential avoidance responses in some bycatch species while remaining compatible with fishing operations (Ortiz et al., 2016; Mangel et al., 2018).

The initial experimental design consisted of three observation platforms (Figure 1), each comprising a surface buoy supporting four GoPro cameras and red LED lights arranged in a horizontal array to give a 360° view, with one additional downward-facing camera. In the test configuration, a single green LED light was positioned between the buoy and camera array, with the light omitted/absent from the control set-up. Platforms were deployed within the corridor before dusk using a DOC vessel and retrieved the following day. Due to low underwater visibility, this design was subsequently abandoned in favour of a grid-based approach and human/above water observations.

For the second approach, a 5 m grid was placed across the corridor to maximise encounter probability (Figure 2). The grid comprised three surface buoys spaced 2.5 m apart (0, 2.5, and 5 m). Red LED lights were mounted approximately 2 m below the buoys in a 360° horizontal configuration to illuminate the grid area. The visual sensitivity of penguins is tuned to lower wavelengths (i.e., violet, blue and green; Hadden and Zhang, 2023) and therefore penguins have low sensitivity in the higher wavelengths (i.e., red). Four green LED lights were attached to the top of the grid and seven to the bottom. Weights attached beneath each red-light-array maintained grid shape. This configuration created two illuminated frames with open centres, allowing penguins to swim freely through the grid. The grid was deployed and secured to the

jetty and wharf as shown in Figure 2c) placing it across the pathway of the smaller group of penguins transiting through the inner harbour.

2.3   Experimental Design: Data collection.

The second approach relied on observations being made by observers located on the wharf due to the low underwater visibility (Figure 3). Trial details and penguin observations were recorded electronically using a Google Form. Recorded variables included trial start time and date, weather conditions, presence of other artificial lights, estimated water visibility, and general comments. Counts were made of little penguins moving through/within predefined spatial zones relative to the grid (Figure 3). General behaviour of the penguins in the area around the grid were described from video footage during the trials and included changes in swimming speed, direction or swimming style (i.e., head above water, swimming underwater, circling).
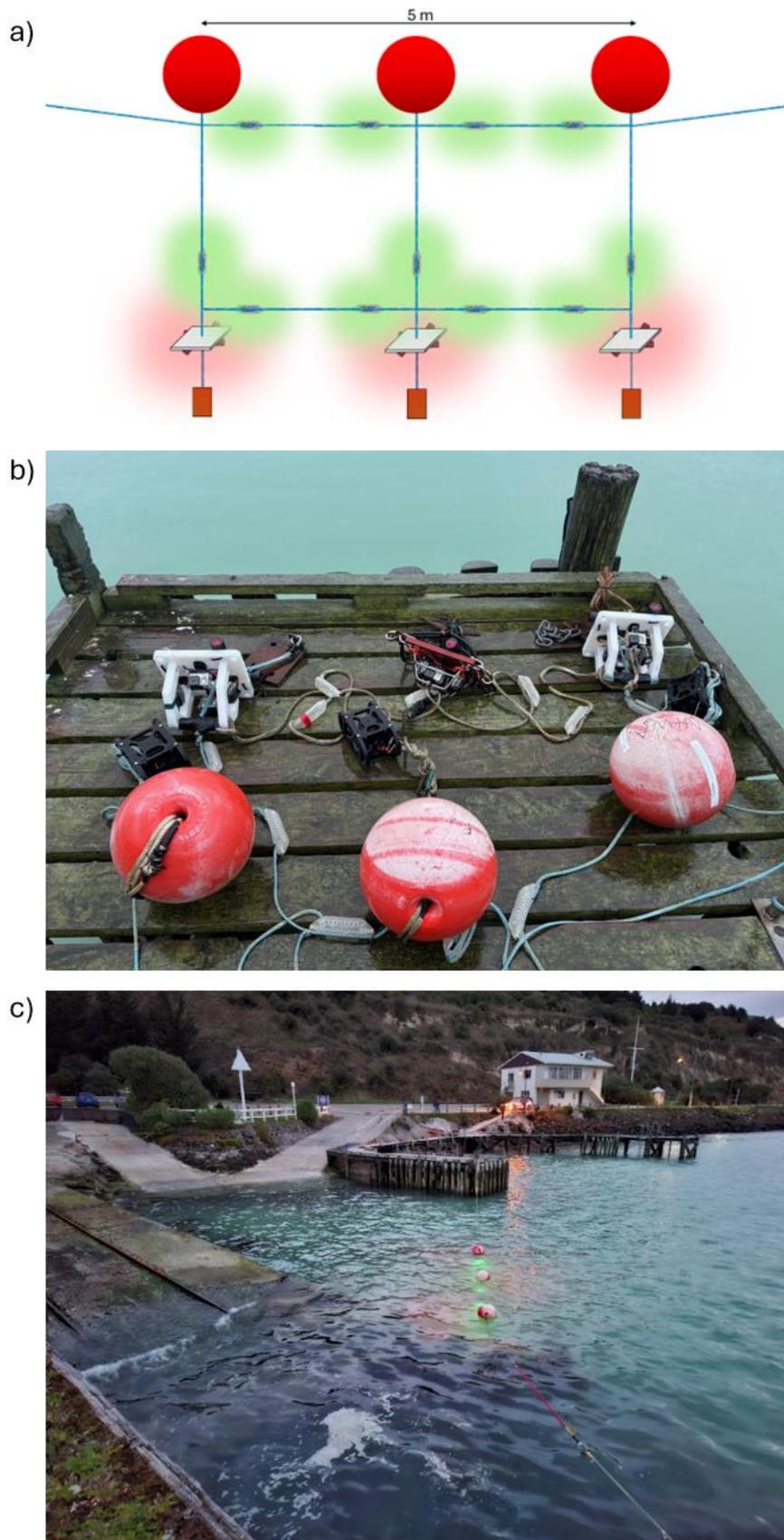
a)

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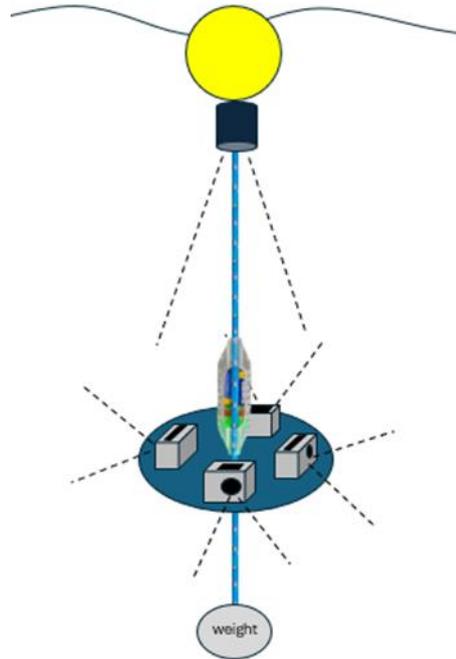
c)

Figure 1:   The initial approach.   a) Fishtek Marine NetLights. The green LED lights had a wavelength of around 520 nm. b) Systematic drawing of the observation platform. Four Go Pro cameras arranged around the light source and one pointing down towards the light. c) image of three observation platforms (red buoys in image) deployed in the inner harbour.

Figure 2: **The second approach.** a) Systematic drawing of the 5 m long grid placed between the jetty and slipway. b) Equipment prior to deployment. (c) Image of grid deployed in the inner harbour.

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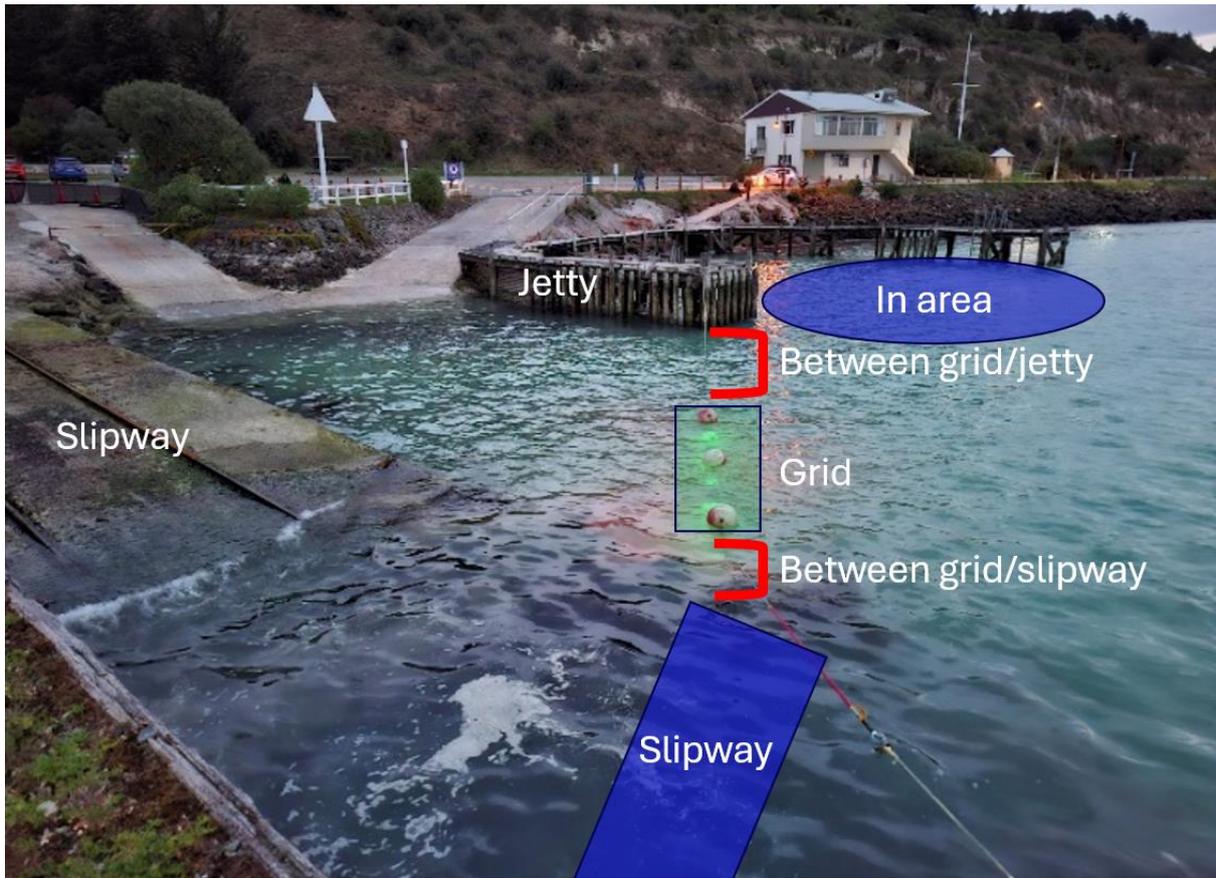
Figure 3: **Annotated view of the observation zones recorded during the trial from the wharf.** Grid – area between the first and last buoy. Between grid/jetty – from the grid buoy to the jetty. Between grid/slipway – from the grid buoy to the slipway. Slipway – area above the slipway. In area – area on the other side of the jetty.

3 Results

Nine grid trials were conducted between 3–18 October 2025 (Table 1). A total of 168 observations of little penguins moving to and from their burrows were recorded; with 158 observations occurring within approximately 5 m of the grid (Table 2; Figure 3). After trial 6, the grid was repositioned slightly closer to the slipway to increase encounter likelihood.

Of the 68 observations near the grid when green LED lights were not illuminated, there were five observations of penguins swimming through the grid. In each case, penguins approached the grid at a steady swimming speed and passed through without an obvious change in speed or direction (Figure 4a–c), before exiting the water at either the ramp or adjacent rocks. In the remaining 63 observations, penguins passed within approximately 5 m of the grid but did not interact with it.

Of the 90 observations made when green LEDs were illuminated, no penguins swam through the grid or directly interacted with it. Most penguins continued their trajectory apparently unaffected by the illuminated grid. There were two observations of penguins altering their swimming speed and direction in response to the grid (Figure 4d–f; marked with * in Table 2). In these instances, penguins approached the grid before stopping, lifting their head above water, and then swimming around it.

Table 1: **Trial details.** The grid was left overnight twice (indicated by *) and additional observations were recorded the following morning.

Trial	Date	Penguin movement	LED	Grid placement
2	3/10/2025	To burrows/ night	Yes	Between jetty and slipway
3	4/10/2025	To burrows/ night	No	Between jetty and slipway
4*	5/10/2025	From burrows/ morning	No	Between jetty and slipway
5	5/10/2025	To burrows/ night	Yes	Between jetty and slipway
6*	6/10/2025	From burrows/ morning	Yes	Between jetty and slipway
7	15/10/2025	To burrows/ night	Yes	Between jetty and slipway, closer to slipway
8	16/10/2025	To burrows/ night	No	Between jetty and slipway, closer to slipway
9	17/10/2025	To burrows/ night	No	Between jetty and slipway, closer to slipway
10	18/10/2025	To burrows/ night	Yes	Between jetty and slipway, closer to slipway

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Table 2: **Number of penguins observed in each zone per trial.** Description of zones can be found in Figure 3. * Indicates the observations of a little penguin stopping and swimming around the grid with green LEDs.

Trial	Date	Movement	Green LED	Number of little penguins				
				Through grid	(between grid - slipway/ jetty)	Slipway	In area (other side of jetty)	Total
2	3/10/2025	To burrows	Yes		2	16	4	22
3	4/10/2025	To burrows	No	1	5	13	2	21
4	5/10/2025	From burrows	No		2	11		13
5	5/10/2025	To burrows	Yes		2	17	1	20
6	6/10/2025	From burrows	Yes			18		18
7	15/10/2025	To burrows	Yes		3*	5		8
8	16/10/2025	To burrows	No	3		21	1	25
9	17/10/2025	To burrows	No	1	4	7	1	13
10	18/10/2025	To burrows	Yes		4*	23	1	28
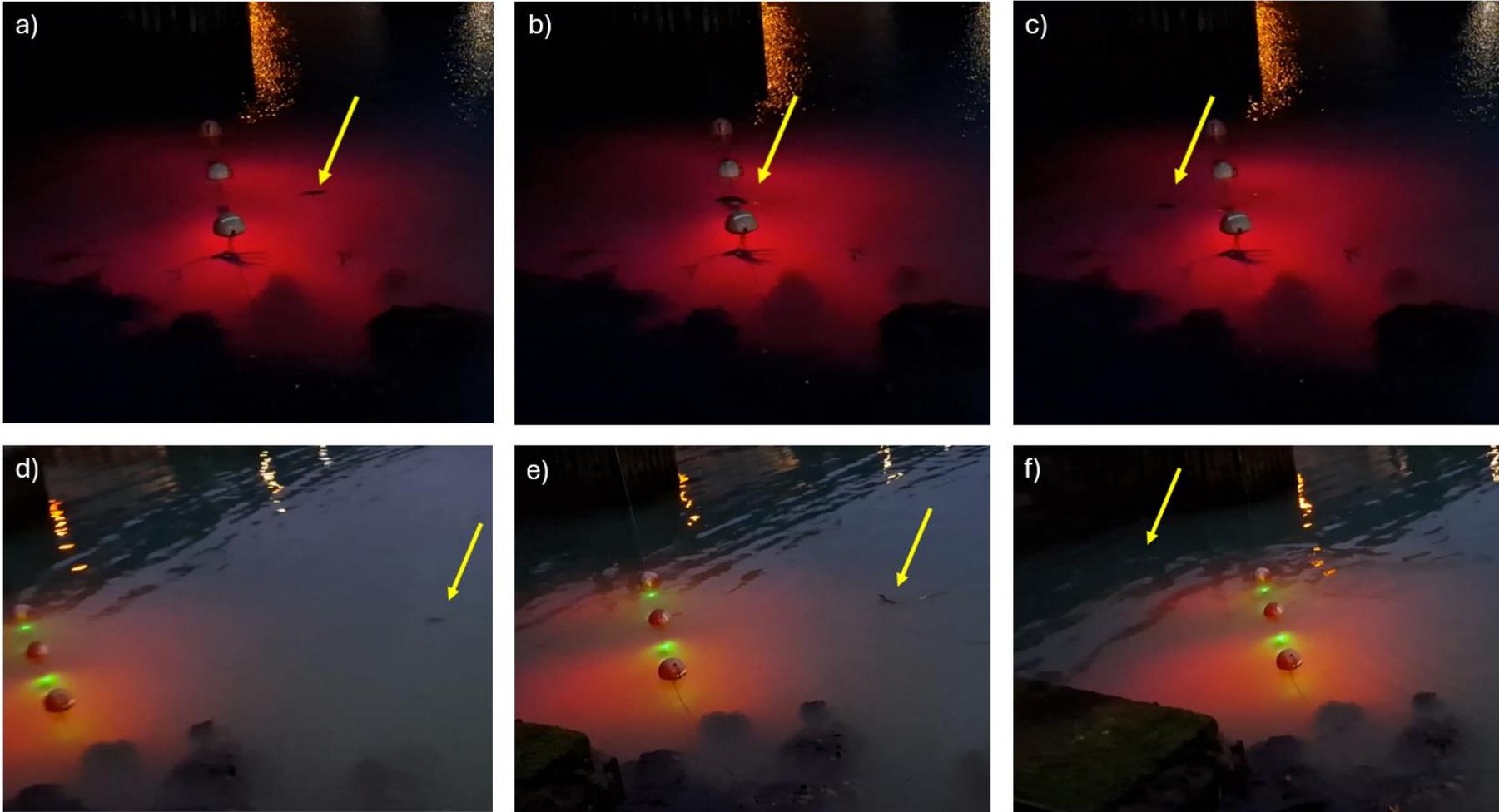
Figure 4: **Frames from footage showing the reaction of penguins to the grid without green LEDs (a-c), and with green LEDs (d-f).** The penguin swimming towards the shore swims toward the grid (d), stops and lifts its head above the water (e), before changing direction and swimming around the grid (f).

4   Summary and recommendations

A total of 168 observations of penguin movement in the vicinity of the experimental array were recorded, with 158 assumed to have occurred with the array and green LED lights being within the effective field of view of those penguins. There were only five observations of penguins passing through the grid when the green LEDs were omitted/absent, and only two observations of penguins stopping briefly and swimming around the grid when green LEDs were illuminated. Importantly, no penguins were observed moving directly towards, circling, or interacting in any other way with the illuminated grid, i.e., there was no evidence of attraction to the green LED lights.

These findings should be interpreted and extrapolated with caution, as the study was preliminary and carried out with little penguins rather than hoiho. Observations were made while penguins were transiting between foraging areas and burrows, a behavioural state that may differ from active foraging in deeper waters where they may encounter set nets. The experiment also did not include the presence of fish caught in a net as a factor/variable.

However, the lack of attraction observed to the LED lights does indicate a likely low risk of progressing to LED trials in a fishing context, provided these are undertaken under close observation with clearly defined stop/go decision rules. The results support advancement to the Fisheries New Zealand project PRO2024-03 to assess the effects of green LED mitigation in operational set net fisheries on both target catch and protected species bycatch. Recommended observation/stop/go rules may include: 1) stopping fishing trials if any penguin is captured, injured, or killed on a net fitted with green LED lights; or 2) stopping fishing trials if observations suggest that penguins may be attached to, investigate, follow, or remain in close proximity to the illuminated sections of set nets during setting or hauling, or if repeated approach behaviour is observed within a single fishing event. Additionally, a review may be warranted if penguin behaviour around green LED-equipped nets appears consistently different from behaviour observed around the control (non-green LED) nets under comparable conditions.

Noting the caveats identified previously, further work could strengthen inference around penguin responses to green LEDs. Additional data of the same format near a hoiho colony would be beneficial. We would recommend that ideally future trials should aim to be conducted in known penguin foraging grounds if feasible, including areas used by other species, particularly yellow-eyed penguins (hoiho), to assess the broader applicability of findings across species and behavioural contexts.

5 Management implications

The absence of observed attraction of little penguins to green LED lights in this non-fishing context suggests that the use of green LEDs as a mitigation measure in set net fisheries is unlikely to increase penguin interaction risk. These findings support a precautionary, staged progression to carefully monitored fishing trials, with clear stop/go decision rules and ongoing assessment of protected species interactions. Results from this study have provided evidence to inform fisheries management decisions regarding the potential adoption of LED-based mitigation, while highlighting the need for species- and context-specific evaluation before broader implementation.

6   Acknowledgements

7   References

Beentjes, M.P., Bian, R. (2022). Characterisation of commercial fishing activity overlapping with South Island hoiho (*Megadyptes antipodes*) distribution. *New Zealand Aquatic Environment and Biodiversity Report No. 297*: 92.

Bielli, A., Alfaro-Shigueto, J., Doherty, P.D., Godley, B.J., Ortiz, C., Pasara, A., Wang, J.H., Mangel, J.C. (2020). An illuminating idea to reduce bycatch in the Peruvian small-scale gillnet fishery. *Biological Conservation 241*: 108277. <http://dx.doi.org/https://doi.org/10.1016/j.biocon.2019.108277>

Field, R.H., Crawford, R., Enever, R., Linkowski, T.B., Martin, G.R., Morkūnas, J., Morkūnė, R., Rouxel, Y., Oppel, S. (2019). High contrast panels and lights do not reduce bird bycatch in Baltic Sea gillnet fisheries. *Global Ecology and Conservation, 18*: e00602. <http://dx.doi.org/https://doi.org/10.1016/j.gecco.2019.e00602>

Hadden, P. W., Zhang, J. (2023). An overview of the penguin visual system. *Vision*, *7(1)*: 6.

Mangel, J.C., Wang, J., Alfaro-Shigueto, J., Pingo, S., Jimenez, A., Carvalho, F., Swimmer, Y., Godley, B.J. (2018) Illuminating gillnets to save seabirds and the potential for multi-taxa bycatch mitigation. *Royal Society Open Science, 5(7)*: 180254. <http://dx.doi.org/doi:10.1098/rsos.180254>

Ortiz, N., Mangel, J.C., Wang, J., Alfaro-Shigueto, J., Pingo, S., Jimenez, A., Suarez, T., Swimmer, Y., Carvalho, F., Godley, B.J. (2016). Reducing green turtle bycatch in small-scale fisheries using illuminated gillnets: the cost of saving a sea turtle. *Marine Ecology Progress Series, 545*: 251-259.

Yochum, N., Karlsen, J.D., Senko, J.F., Wang, J.H., Melli, V., Luca Geraci, M., Utne-Palm, A.C., Breen, M., Cuende, E., Bayse, S.M., Somerville, J., Hermann, A., Edridge, A., Mackenzie, E.K., Ljungberg, P., Chladek, J., Van Opstal, M., Watson, D., Lomeli, M.J.M., Oliver, M. (2024). Guidelines for Evalua,ting Artificial Light to Mitigate Unwanted Fisheries Bycatch. *Reviews in Fisheries Science & Aquaculture, 32(4)*: 612-656. <http://dx.doi.org/10.1080/23308249.2024.2359417>

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