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SCIENTIFIC EXPERIMENT TO EVALUATE DOLPHIN COW-CALF SEPARATION DURING PURSE SEINE FISHING OPERATIONS IN THE EASTERN TROPICAL PACIFIC OCEAN: PROGRESS SUMMARY REPORT

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EXECUTIVE SUMMARY

The aim of this project is to use unmanned aerial vehicles (UAVs) to determine: (i) if dolphin mother-calf pairs become separated during chase, encirclement, backdown, and/or post-release "run" from the purse-seine net; and (ii) the rate at which mother-calf separation may be occurring and potentially affecting population growth of dolphins in the Eastern Tropical Pacific (ETP). The project includes a two-phased pilot study followed by a main study, and started in May 2023. The first phase of the pilot study occurred from May to July 2023 off the south of Portugal where we developed our UAV protocols by observing common dolphins at our long-term study site. The second phase of the pilot study occurred during August 2023 aboard a Mexican-flagged tuna purse-seiner where we became familiar with fishery operations, tested and refined our methods, and collected preliminary data. Calves were followed in eight of the ten fishing sets sampled via UAV. Working definitions for key terms were developed. The main study started in May 2024 aboard a Mexican-flagged tuna purse-seiner and this phase is still on-going.

Overall Project Aim

The aim of this project is to use unmanned aerial vehicles (UAVs) to determine: (i) if dolphin mother-calf pairs become separated during chase, encirclement, backdown, and/or post-release "run" from the purse-seine net; and (ii) the rate at which mother-calf separation may be occurring and potentially affecting population growth. These results will help to inform population models and management and conservation actions for dolphins in the ETP.

Overview of Study Design and Pilot Study Objectives

Our study design includes a two-phased pilot study, followed by the main study. At this stage, we have completed both phases of the pilot study. The first phase of the pilot study occurred at our study site off the south of Portugal. The second phase of the pilot study occurred aboard a purse-seiner in the ETP.

<u>Our objectives for the first phase of the pilot study were to:</u>

1) test and become proficient with two new UAVs (DJI Matrice 30T multi-rotor quadcopter and Autel Dragonfish Standard fixed-wing aircraft),

2) test UAV performance (e.g., with respect to battery life, wind),

3) assess video quality under varying environmental conditions,

4) test the resolution of the visible light and infrared cameras at various heights to determine the maximum height at which we can fly the UAVs and still extract metrics for assessing mother-calf separation, and

5) refine image analysis techniques.

<u>Our objectives for the second phase of the pilot study were to:</u>

1) apply the UAV methods used during pilot study phase 1 to a purse seiner in the ETP;

2) become familiar with fishery operations, the behavior of the dolphin species of interest, and working under various fishery and environmental conditions in the ETP;

3) determine the optimal UAV(s) and camera(s) for use during the main study (e.g., according to image resolution, battery duration);

4) develop metrics to define mother-calf separation;

5) determine if mother-calf separation can be observed in real time; and

Progress and Learnings: Pilot Study, Phase 1 – Portugal

<u>Research Effort</u>

Phase 1 of the pilot study was conducted off the south of Portugal at AIMM's long-term study site. Two small dolphin species – the common dolphin (*Delphinus delphis*) and the bottlenose dolphin (*Tursiops truncatus*) - regularly occur in this area, making this an appropriate area in which to conduct the first phase of the pilot study. From 29 May to 27 July, 2023 research trips occurred from AIMM's 7-m research vessel leaving from the harbor of Albufeira, Algarve, Portugal. During this time, 40 research trips were conducted, totaling 200 h 25 min. of survey effort (average survey duration = 5 h). This yielded 67 UAV flights, totaling 7 h 37 min of flight time and a distance of 32.3 km. Some of these flights (n = 47) were practice flights over land. The rest (n = 20) occurred at sea, yielding 149 minutes of video flying over dolphins. All project personnel participated in this phase of the pilot study.

<u>Learnings</u>

We became proficient with flying the Matrice M30T. The landing platform on our research vessel (*Ketos*) was 1.5 m x 1.5 m, and we determined that we could safely operate the Matrice up to sea conditions of Beaufort 3 and 1 m swell. Above that threshold, it became challenging to land the drone due to the rocking of the vessel which confused the UAV flight control system. However, we recognized that this landing platform was likely to be much smaller than that on the tuna purse-seiner and that in the ETP, we could likely operate under rougher sea conditions.

Considering the stringent environmental conditions, we were still able to obtain ample drone imagery of dolphins to test the resolution of the visible light camera and refine our image analysis techniques.

We also designed a series of land trials to determine the real-life size of a pixel (on the computer screen) according to a UAV flying at 90° at various height and zoom combinations (Fig. 1). For example, at a drone height of 100 m using 9x zoom, we determined that each pixel measures 0.039 m. This will be useful for obtaining absolute measurements of dolphins in the ETP, particularly to ascertain calf age based on established age-length relationships. However, we recognize that this requires the UAV to be flown 90° above the dolphins, which is not always possible due to sun glare.

We also determined the field of view at various UAV heights during our land trials (Fig. 2). This helped us to understand at what heights we may need to fly in the ETP to image different sizes of dolphin groups (e.g., very large groups would likely take up more space and require a higher

Pixel Size

Zoom \ height	20	30	40	50	75	100	150	200	250	300	400	500
2	0,361	0,556	0,714	0,938	1,329	1,810	2,763					
3,2	0,227	0,352	0,457	0,590	0,897	1,129	1,750	2,333				
4,4	0,166	0,254	0,327	0,432	0,656	0,789	1,193	1,641				
5	0,142	0,216	0,281	0,352	0,528	0,695	1,040	1,438	1,780			
6	0,117	0,181	0,234	0,296	0,449	0,590	0,882	1,180	1,479			
7	0,101	0,154	0,201	0,254	0,372	0,495	0,750	1,010	1,250			
8	0,089	0,136	0,176	0,221	0,328	0,441	0,660	0,897	1,105			
9	0,078	0,122	0,157	0,198	0,292	0,390	0,590	0,795	1,000			
10	0,070	0,109	0,140	0,177	0,261	0,348	0,517	0,705	0,890	1,050	1,382	1,694
12		0,089	0,117	0,147	0,220	0,288	0,432	0,587	0,734	0,861	1,167	1,438
14		0,077	0,100	0,127	0,189	0,251	0,376	0,498	0,640	0,739	1,000	1,235
16		0,068	0,087	0,110	0,164	0,219	0,329	0,438	0,559	0,648	0,861	1,061
18		0,060	0,078	0,098	0,146	0,195	0,291	0,386	0,498	0,574	0,772	0,955
20				0,088	0,131	0,176	0,263	0,350	0,438	0,520	0,691	0,875
24				0,073	0,110	0,146	0,219	0,292	0,361	0,427	0,577	0,719
28				0,063	0,094	0,125	0,188	0,251	0,314	0,370	0,495	0,618
32				0,055	0,082	0,110	0,163	0,219	0,274	0,323	0,429	0,544
36					0,073	0,097	0,145	0,194	0,244	0,288	0,386	0,479
40					0,065	0,088	0,131	0,174	0,219	0,260	0,347	0,432
48						0,073	0,108	0,145	0,184	0,216	0,289	0,360
56						0,063	0,093	0,126	0,155	0,186	0,247	
64							0,082	0,108	0,137	0,161	0,216	0,269
72							0,073	0,097	0,121	0,144	0,193	0,241
80								0,087	0,109	0,130	0,173	0,216
96								0,072	0,090	0,108	0,145	0,180
112								0,062	0,079	0,093	0,123	0,155
128								0,054	0,068		0,108	0,134
160								0,043	0,055	0,065	0,087	0,107

FIGURE 1 (above). Calculated pixel size (m) according to Matrice M30T altitude (m) and zoom.

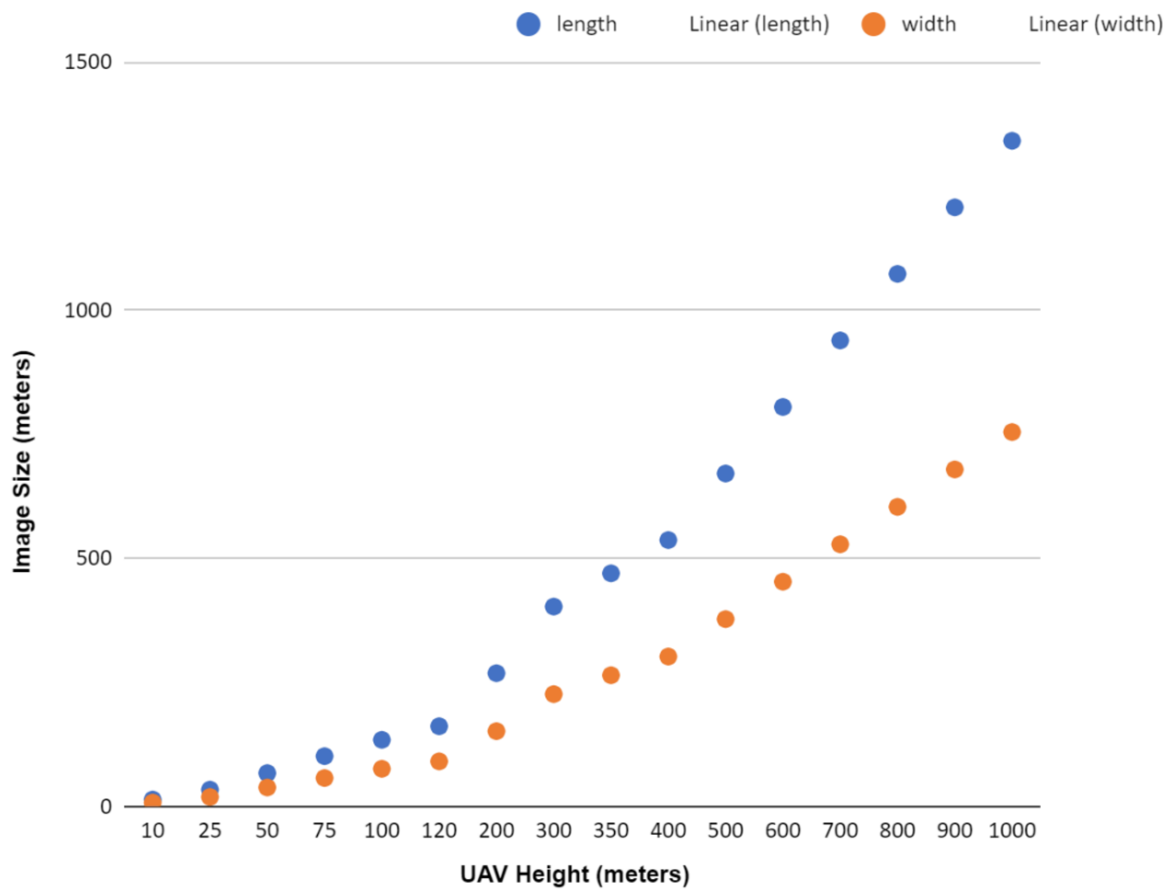

FIGURE 2 (left). The size (field of view) of a 4K image from the Matrice 30T when flown at various altitudes. The points beyond 500 m are extrapolated.

UAV altitude). Overall, the camera resolution was very good and as we had expected based on the advertised specifications (e.g., 4K, 12 MP). Given our years of work with lesser quality drones and cameras, the improvement in image quality was impressive. For example, during our land trials, we were able to discriminate a pixel size of 0.107 m at 160x zoom.

Finally, another important exercise during the first phase of the pilot study was to determine how much data storage each UAV flight required. This helped us to plan our data storage needs and determine how many and what sizes of hard drives would be required for the ETP pilot study.

We also analyzed the thermal imagery and concluded that it is not a useful tool for our study. Contrary to our predictions, we were unable to see outlines of the dolphins' bodies as they broke the surface of the water. It is likely that the film of water nearly constantly covering the dolphins' bodies prevented us from detecting a thermal signal.

Challenges

We encountered some technical difficulties with our new UAVs during the Portugal pilot study. However, getting familiar with these new systems and trouble-shooting technical issues that arose was an objective of this first part of the pilot study.

First, we had and continue to experience on-going problems with the Matrice thermal camera. During playback, the imagery repeatedly freezes about every 4 sec. This issue persists even after we sent the unit back to DJI for repair. We are continuing to work with DJI to resolve this issue, which will likely involve getting an entirely new unit. Fortunately, as we already determined that the thermal camera is not effective for our study, this has not slowed our progress.

Second, we also faced multiple challenges in ordering and obtaining the Dragonfish. This issue arose from the fact that we require a mobile base station (the ASAT) since we will be flying the Dragonfish from a moving vessel. We were the first team in the world to purchase this new, cutting-edge technology and there were many details to work out with Autel. After numerous discussions with the Autel engineers in China and dealers in China and Portugal spanning several months, we determined the only way for us to receive the Dragonfish in time for the ETP pilot study was for a member of our team (Cid) to fly to Autel headquarters in China. This was a successful trip and Cid received the required training with the Dragonfish and ASAT. Despite our best efforts, however, there were still multiple delays in the shipment of the Dragonfish from China to Portugal, and the drone did not arrive in time for use in the ETP pilot study. The unit arrived in Portugal in October 2023 and our training program commenced in November with the local Autel trainer.

During our first days of training with the Dragonfish, we experienced some unpredictable issues with connectivity between the UAV and the ground station (ASAT). Therefore, the ASAT was out for repair from 5 Dec 2023 to 18 Jan 2024. Once the ASAT was returned and the connectivity issue was overcome, the team in Portugal has conducted intensive testing with the UAV and ASAT. Still, the fact that our unit is the "first of its kind" has brought some unexpected problems and as such we are still trouble-shooting some other small issues with the manufacturer (Autel) support team.

Our training progressed steadily. In three different training sessions, we flew the Dragonfish from coastal areas in Portugal to access the Atlantic Ocean. These sessions were particularly useful for testing the different cameras of the UAV in real scenarios, as well as the different camera lens filters. Unfortunately, dolphins were not spotted during these flights.

It has not yet been possible to operate the Dragonfish from a vessel in Portugal. Before we next depart for the ETP, we aim to conduct at least one test from a vessel where we fly the Dragonfish over dolphins in Portugal. Other goals before we leave for the ETP are to improve our mastery of the Dragonfish flight controls and AI use, and to increase the maximum distance flown.

Our top achievements with the Dragonfish are as follows:

- Total flight time: 16:50:00 (hh:mm:ss)
- Total distance: 995.2 km
- Total number of flights: 77
- Longest flight duration: 1.1 hours (29% battery when landed)
- Longest flight distance: 73.3 km
- Two fully manually-operated flights – 00:16:45 (hh:mm:ss) and 9.5 km
- Longest distance from ASAT: 14 km (with good reception)

Progress and Learnings: Pilot Study, Phase 2 - ETP off México

Research Effort

Phase 2 of the pilot study occurred off the coast of México from August 10-24, 2023 (15-day trip). Three team members (Pearson, Castro, Cid) left from the port of Mazatlán aboard a Mexican-flagged tuna purse-seine vessel. The first tuna set occurred on Aug. 11. We did not collect any data during this first set as our goal was to observe and become familiar with the fishery operation and timings of the various phases (e.g., spotting the dolphins, chase, encirclement, forming the backdown channel, release). The next set occurred on Aug. 13 and was our first sampling period. In total, we observed 15 sets and collected data during 10 of those sets (Table 1). Only spotted and spinner dolphins were observed during these 10 sets.

TABLE 1. Summary of fishery sets and data collected aboard the purse-seiner, Aug. 10-19, 2023.

Set No	Sample No	Date	Start Time	Set Aborted?[a]	Fishery Phase – Imaged with UAV?			Calves Followed?
					Chase	Encirclement	Backdown	
1	n/a	8/11	15:45	no	no	no	no	n/a
2	1	8/13	11:00	no	no	yes	no	n/a
3	n/a	8/13	14:45	yes	n/a	n/a	n/a	n/a
4	2	8/14	9:28	no	partial	yes	yes	yes
5	3	8/14	12:34	no	no	yes	yes	yes
6	n/a	8/14	14:30	yes	n/a	n/a	n/a	n/a
7	4	8/15	11:31	no	no	yes	yes	yes
8	5	8/15	17:35	no	no	yes	yes	yes
9	6	8/16	8:12	no	no	yes	yes	no
10	n/a	8/16	10:30	yes	n/a	n/a	n/a	n/a
11	7	8/16	13:17	no	no	yes	yes	yes
12	8	8/16	16:31	no	no	yes	yes	yes
13	9	8/18	11:33	no	partial	yes	yes	yes
14	10	8/19	10:50	no	no	yes	yes	yes
15[b]	n/a	8/19	14:00	no	n/a	n/a	n/a	n/a

[a] Reasons for a set being aborted by the fishery included the tuna and/or dolphins escaping from the net and not enough tuna remaining with the dolphins after the group was split.

[b] Set not imaged due to the rough seas which caused the UAV to crash upon take-off.

On the morning of Aug. 20, we were transferred to another vessel for transit back to Mazatlán, where we arrived the morning of Aug. 24.

Learnings

Environmental conditions

From Aug. 14-19, we recorded our geographic position and weather conditions (i.e., Beaufort sea state, swell, cloud cover, visibility) hourly from approximately 07:00-19:00. Most observations occurred in Beaufort >3 (Fig. 3) and >1 m swell (1 m = 40%, 1.5 m = 24%, 2 m = 36%).

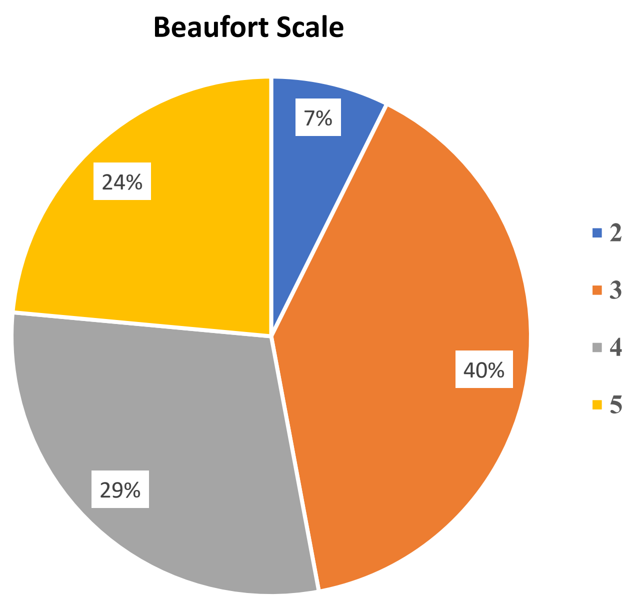

FIGURE 3. Beaufort sea state as recorded on our hourly weather log from 7:00-19:00.

The seas were rougher than we had expected, based on data previously obtained from the IATTC observer program indicating that most sets from August to mid-November 2017-2022 occurred at a Beaufort sea state ≤ 3. The presence of Hurricane Hilary likely caused rougher conditions than normal. In addition, based on our conversations with the crew, we learned that August seas are typically rougher than other times of the year. Despite these conditions, we were able to fly the UAV during each set except for the last set on Aug. 19 (Set 15, Table 1) where the UAV crashed twice on the deck during take-off due to the large >2 m swell. Fortunately, no one was injured and the UAV was recovered and will be sent to DJI for repair before the main study.

The sun glare also posed a problem to the quality of the videos, due the high movement of the surface of the ocean. We had to place polarized filters on the camera to minimize the problem and sometime prioritize image quality over having the image at 90º degrees.

Understanding Fishery Operations

By watching 15 tuna sets, and imaging 10 of them, we developed a good understanding of this complex, multi-phased fishery operation. Briefly, the dolphins are first spotted using the radar, big-eye binoculars, or the helicopter. Once spotted, the helicopter initiates the chase by dropping *bengalas* (flares) to herd the dolphins. The speed-boats (typically six) are then released to chase the dolphins into the net. Ink bombs dropped at the net opening, pangas driving in tight circles, and loud hammering are also used to prevent the dolphins' escape until the net is closed. After a period of approximately 30-45 minutes, the backdown channel is formed and swimmers/divers enter the net to help to release the dolphins. During the release, speed-boats may also be driven in tight circles at the net perimeter to herd the dolphins towards the backdown channel.

The helicopter pilot worked closely with our UAV pilot (Cid) to develop a safety plan which included fly/no-fly corridors for the UAV and helicopter to ensure everyone's safety. This coordination between the helicopter and the drone was essential to the safe success of the study.

Protocol Development

We developed and adapted our data collection protocol to each fishery phase as follows.

<u>Chase</u>: Since we did not have the Dragonfish, and due to the limited range and battery life of the Matrice M30, we obtained only two partial samples of the chase. These samples were opportunistic in nature. We flew > 47 min and recorded approximately 25 min of video during these two samples. Despite this small sample size, we managed to record and observe multiple mother-calf pairs. Additional information for future consideration was recorded, including dolphins' behavior/reaction to the fishery and group dispersion. We are in the process of reviewing that footage and will use it to develop a protocol for imaging and analyzing the chase during the main study.

<u>Encirclement</u>: Once the net was fully closed, we launched the UAV. Our goal was to obtain an estimate of group size and composition (i.e., no. individuals according to species and size class).

We used three screens to observe the group: the pilot's remote control screen, the second remote control screen, and an external 27" HD monitor. This allowed all three team members to closely observe the group, paying particular attention to the number of adults and calves, and species identification.

As groups were typically too large and dispersed to be imaged in one frame, we developed a technique called "scrolling the group" where we would slowly fly from one edge of the group to the other, noting the start and end times of the scroll. We did this multiple times, typically during the latter part of encirclement when the group became more cohesive as the net was decreasing in diameter as it was being pursed. As much as possible given sun glare, we flew at 90° to enable absolute size measurements of calves (defined in Table 2) which can be used to estimate calf age. The estimated group size and number of calves was obtained from this "scrolling of group" method.

<u>Backdown/post-release run:</u> The optimal viewing position for backdown was the helideck. The UAV pilot (Cid) and UAV observer (Pearson) watched the dolphins on the remote control screens while the net observer (Castro) used binoculars to monitor the backdown channel and watch for the signal from the backdown channel controller indicating a mother-calf pair was leaving the net. This was then communicated to the UAV team so that we could increase our chances of following a mother-calf pair. At all times, the net observer also kept an eye out for calves exiting (either on their own or assisted by a diver) the net alone and lone calves swimming outside the net perimeter. We followed mother-calf pairs leaving the net as much as possible. Our longest follow of a single mother-calf pair was 9 min 33 sec, covering a distance of approximately 2.2 km.

TABLE 2. Interim definitions of key terms used in the pilot study. These may be refined as analysis continues.

Term	Definition
Calf[1]	With an adult: - An individual approximately ≤ 80% the size of an adult and swimming in association with an adult, either in echelon position (swimming alongside the adult) or infant position (i.e., swimming underneath the adult) most of the observed time. Without an adult (lone calf): - When size is assessable: an individual approximately ≤ 80% the size of an adult, observed approximately ≥ 1 body length from the nearest adult neighbor and not in echelon or infant position[2]. When size is not assessable: an individual that appears overall smaller than an adult, observed approximately ≥ 1 body length from the nearest adult neighbor and not in echelon or infant position[2], showing swimming behavior typical of an animal with under-developed motor skills such as cork-like and chin-up surfacings, and/or quick/erratic movements, rarely remaining still at the surface. Fetal folds (i.e., vertical stripe-like marks along the body) and/or floppy dorsal fin and fluke may also be visible in newborns.
Separation	A lone calf, or a calf observed swimming in echelon position that subsequently loses that position and becomes a lone calf.
Slippage	A calf swimming in echelon position then moving away in the longitudinal or latitudinal direction. May or may not result in separation.
Potential reunion	A lone calf that approaches or is approached by an adult and subsequently swims in echelon position until the pair leaves the field of view. This is deemed a potential reunion as it is challenging to determine if the adult with whom the calf joins is its mother, or even a female, due to a lack of individually-distinct markings on the dolphins and a lack of distinct sex-specific morphological characteristics observable by UAV.
Rejection	A lone calf that approaches an adult, subsequently swims in echelon position, then breaks echelon position by veering away from the adult.

[1] Per definitions in Archer et al. (2001, 2004), Chivers et al. (2019), Hohn and Hammond (1985), Larese and Chivers (2009), Mann (1999), Perrin et al. (1976, 1977, 1979), and Rowe (2010)

[2] During high-speed travel during the chase and post-release run, a calf is expected to remain approximately < 1 body length of its presumed mother in echelon position to maximize hydrodynamic drafting benefits.

Based on analysis of the first three samples, we discovered that mother-calf pairs typically slowed down after approximately 30 sec from leaving the net, thus likely decreasing the probability for separation (Fig. 4). We then developed the decision rule to follow a mother-calf pair for 30 sec, then return to the net to follow other mother-calf pairs in order to increase our sample size.

If a lone calf (as defined in Table 2) was observed, we stayed with it for as long as possible. This was done for lone calves observed outside of the net during backdown or left behind after backdown. Our longest follow of a lone calf was 4 min 34 sec.

Image Analysis

Image analysis was conducted in VLC Media Player using 4K monitors, slowing down playback and watching/re-watching multiple times second by second as much as necessary.

Encirclement: We selected the three best group scrolls during each set to count all individuals by species and relative calf size. We then used the highest values recorded for group size and number of mother-calf pairs for each set, based on the logic that we were still likely missing some animals during the group scrolls (e.g., due to diving animals, animals moving off the screen, etc.). The number of mother-calf pairs observed inside the net during encirclement constitutes the denominator for the separation and slippage coefficients calculated overall and for each release (see section "Estimators for separation and slippage" ahead).

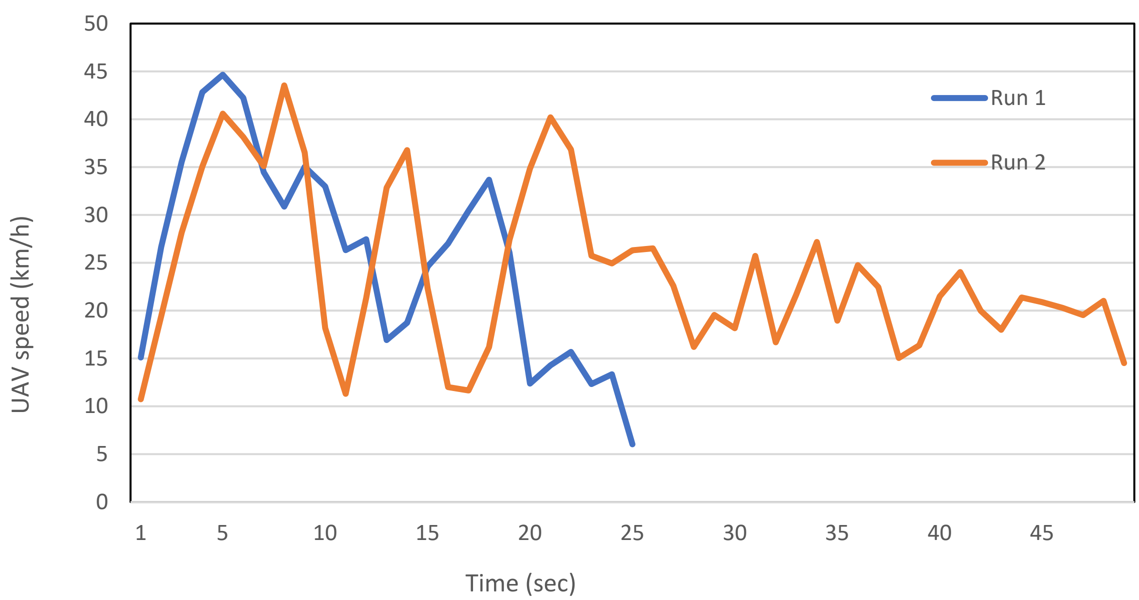

FIGURE 4. UAV speed recorded during two follows ("runs") of mother-calf pairs leaving the net during sample no. 10.

Backdown/post-release run: For each mother-calf pair observed leaving the net, we recorded the timestamp and relative calf size (as a proxy for calf age). For this initial analysis, we recorded each calf as being ≤ ½ the length of an adult or > ½ the length of an adult, based on a visual estimation of size. Animals approximately ≤ ½ the length of an adult are considered neonates (Archer et al. 2001; Hohn and Hammond 1985; Perrin et al. 1977, 1984). Further, for this initial analysis, we were not always able to make a definitive species identification of animals outside the net.

We followed a mother-calf pair on the screen until they left the field of view, noting the start and end times. This allowed us to monitor for separations, potential reunions, rejections, and slippages, while also providing the best estimate of the proportion of mother-calf pairs observed (sampled) for separation or slippage. If a calf separated, or was initially observed alone, we recorded the timestamp, its species, and relative age, and followed it until it left the field of view or we were unable to continue following it (e.g., due to diving behavior, sun glare, UAV battery life).

Preliminary estimators for separation and slippage

The overall separation coefficient (*S*) defined below is an indicator of the potential rate for permanent separation, based on the backdown/post-release run phase (i.e., not including the chase at this stage). It is beyond the scope of the present project to assess true, permanent separation for several reasons. First, this would require that each mother and each calf be uniquely marked. This is so that a lone calf could be reliably identified and followed for prolonged periods of time (likely days) to assess if a reunion occurred with its mother. Even if a calf is observed to join with another adult, if that adult is a male or a non-lactating female, the calf will not receive nourishment and would likely die of starvation. While it is possible that a calf could join with a lactating female, there is no scientific documentation of allo-nursing in these species of dolphins, so it is not possible to determine if the calf would receive nourishment even if it did join with a lactating female. Based on our photo-identification images taken during encirclement, the mark rate (i.e., the proportion of dolphins that had individually distinct markings) was extremely low, making it impossible to identify and track individuals in the group based on natural, individually-distinct markings. For these reasons, we consider the S estimates below to be indicators of the potential rate of permanent separation. Further, we report "potential reunions" for the reasons mentioned above. However, a future tagging/marking study would help to better assess true, permanent separation and true reunions.

Our preliminary estimators are based on the total number of mother-calf pairs observed inside the net across all encirclements (see equations below), as we described in our proposal. However, as we were unable to follow every mother-calf pair released, we would (incorrectly) be assuming that those mother-calf pairs not followed did not separate or exhibit slippage. This leads to the equations below likely underestimating separation and slippage. As we continue to refine our analysis plan, we aim to revise *S* and *P* to reflect total number of calves followed as the denominator, and to develop a method for then scaling up *S* and *P* to all calves observed inside the net during encirclement.

The overall separation coefficient (*S*) is calculated:

$$S = \frac{\text{total no. separations observed outside the net during backdown across all sets}}{\text{total no. mother-calf pairs observed across all encirclements}}$$

The overall slippage coefficient (*P*) is calculated as:

$$P = \frac{\text{total no. slippages observed outside the net during backdown across all sets}}{\text{total no. mother-calf pairs observed across all encirclements}}$$

We also calculated *S* and *P* by relative calf size (≤½ adult body length vs. <½ adult body length) and by sample.

Challenges

While we encountered several challenges, the ETP pilot study was very successful. As previously mentioned, we encountered rougher seas (wind and swell) than anticipated. Still, we were able to achieve our goal of imaging 10 sets. While we were not able to fully image the chase as we did not have the

Dragonfish, we did obtain two partial samples of the chase with the Matrice and that footage is currently being analyzed. Further, we were able to focus on developing and refining our methods for imaging the encirclement, backdown, and post-release run phases.

Next Steps in Pilot Study Analysis

We have identified several priority areas as follows.

1) In collaboration with IATTC staff, continue to improve the *S* and *P* equations.

2) Develop a method for better differentiation of species inside and outside the net. It was easier for us to identify species inside the net as the dolphins were not swimming at high speeds and we had better control over how we could position the UAV over the group (e.g., with respect to altitude, camera angle relative to sun glare). However, we are continuing to revise our image analysis to obtain better estimates of species composition inside the net. Outside the net, because we did not always observe mother-calf pairs or lone calves in real-time, we were not always able to see them on the zoom camera during post-hoc analysis, which requires the animals to be in the center of the field of view. Further, to obtain a larger field of view, the UAV typically flew at a higher altitude during the release than during encirclement, making it difficult to differentiate species. We will continue to analyze our imagery to identify key features that can be distinguished at altitude, such as the darker color and more robust size of adult spotted dolphins vs. the lighter color and thinner body size of adult spinner dolphins.

3) Obtain more precise calf size measurements in order to obtain more precise age estimates based on known age-length relationships. This will help us to refine our preliminary separation coefficients based on size class. We discussed this with the software engineer and he recommended using a large object for which we could obtain precise measurements, such as the skiff at the backdown channel opening, as a reference point. We will also explore the possibility of placing an inclinometer on the UAVs for oblique photogrammetry.

4) Explore the possibility of assessing dolphin travel speed based on UAV speed and/or dolphin fluke beats. This will help us to asses if travel speed is related to the probability of separation or slippage.

5) Examine dolphin travel direction out of the net using the UAV's GPS locations. Knowing the dispersion angles of dolphins leaving the net may help to assess the likelihood for a lone calf to reunite with its mother. Our preliminary observations indicate that individuals tend to fan out in a wide arc as they leave the net.

6) Develop a variance estimator for the S coefficient.

7) Conduct a power analysis to estimate the sample size needed to determine if calf separation could have population-level impacts.

8) Increase our efficiency in analyzing the UAV imagery by using Image-Pro software. We will also work with a software engineer to potentially develop automated/semi-automated techniques for: i) obtaining estimates of group size and composition, ii) measuring mother-calf and nearest neighbor distances, iii) measuring adult and calf absolute and relative size (for obtaining age estimates), and iv) tracking lone calves and mother-calf pairs across the screen.

Recommendations for the Main Study

First and foremost, we will image the chase. We now have the Dragonfish in hand in Portugal and will spend the time from now until the main study becoming proficient with it. The Dragonfish will be used to image the chase. We understand that groups can be quite large (>1,000 individuals) during the chase and we are prepared to develop different protocols for large vs. small groups. For example, if we cannot follow the entire group, we will focus on the back of the group to increase the probability of observing calves separating and falling behind the group. We will start developing the protocol for the chase now and will refine it during the first few days of the main study.

Second, we will use two UAVs to image the release. Both units will be flown simultaneously, each performing its own flight plan while sampling: one UAV (Autel Dragonfish or DJI Matrice) will follow mother-calf pairs leaving the net; a second, smaller UAV (DJI Mavic) will monitor the backdown channel and perimeter of the net to detect and follow lone calves outside the net. Using the Dragonfish during chases in combination with flying two different UAVs during release will help to increase our sample size and quality. We are currently developing the protocol for this method and will refine it during the first few days of the main study.

Finally, the main study started on May 9, 2024 and is still underway. The main study was originally planned for Oct-Nov 2023 and we recommended rescheduling it to late winter/spring 2024. Better weather conditions are expected in late winter/early spring vs. late Fall, and this timeframe also coincides with the late winter/early spring calving peak (Barlow 1984) which may increase our sample size. Delaying the main study also allowed us more time to refine our protocols, continue with our data analysis, and work with the Dragonfish in Portugal. With this shift in the timing of the main study, we also requested a no-cost extension of the contract to 31 December 2024 (currently 31 August 2024) to allow sufficient time for data analysis and writing.

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