UNMANNED AERIAL VEHICLES (UAVs)
The Future of Coastal Surveillance and Hazard Identification

ABSTRACT

Surf Life Saving NSW has been operating Unmanned Aerial Vehicles (UAVs) in a trial funded by the NSW Department of Primary Industries (DPI) over the 2017-18 patrol season. Volunteer lifesavers and Lifeguards completed more than 2600 flights across nine locations on the North Coast from December 2017 to April 2018, identifying marine creatures including sharks, rip currents and other coastal hazards. The trial was part of the larger shark mitigation trial being undertaken by the DPI and included strategies such as tagging/beacons, smart drum lines and netting.

Aerial surveillance provided by the UAVs in this trial is providing necessary data to DPI scientists about shark numbers and behaviours as well as immediate safety outcomes in alerting swimmers/surfers to the presence of a shark. In addition, it allows for identification of Rip Currents and other hazards as well as surveillance for distressed swimmers. In a world-first, two lives were saved in January when a rescue pod was dropped from a UAV to swimmers in distress, inflating on impact and resulting in a successful rescue. The aerial vision 'went viral' and the rescue was viewed more than 10 million times, around the world.

Surveys of beachgoers on the North Coast indicated that 96% of people feel safer at a beach with drone surveillance and 81% strongly agree that drones increase lifesavers' ability to spot rips and other hazards. In all, 94% of beach users would like to see more drones on NSW beaches.

Looking at the results of the trial and identifying challenges to be met in future, this paper examines issues around the use of UAV technology in lifesaving and hazard identification. How should this technology integrate with existing lifesaving assets and networks including council lifeguards? Can the implementation of UAVs provide a low cost solution to protect coastal users? What part do land managers play in leveraging the potential of UAV applications?

Brief History

Like many technologies, Unmanned Aerial Vehicles (hereafter referred to as drones) had its origins in the military. War, it seems, remains the great incubator for innovation and it is only later that the true applications become apparent far beyond the initial scope.

From as far back as Aristotle's 4th century CE Athens, humans have been questioning aerodynamics and the possibility of flight. During the Renaissance Leonardo Da Vinci experimented with the concept of flying machines, and by 1809 Sir George Cayley published the results of his experiments in aerodynamics. By the middle of the 19th century he had been able to "convince" his coachman to be the passenger on the world's first manned glider. No matter how innovative their thinking however, ultimately they were thwarted by the limitations of their contemporary technology.

It is accepted that the first use of a drone, defined in this instance as an unpiloted aerial machine during a military campaign, occurred on July 15 1849 in Venice Italy. The attacking Austrians floated balloons weighed down with explosives for history's opening air raid. On August 29, The Morning Chronicle published a first-hand account of the attack from the officer Franz von Uchatius who is credited as the "balloon bomb's" inventor.

As this edited excerpt shows he believed it was a success.

"On July the 15th, the occasion alluded to in a former letter, when two balloons armed with shrapnels ascended from the deck of the Volcano war steamer, and attained a distance of 3,500

fathoms in the direction of Venice; and exactly at the moment calculated upon, *i. e.*, at the expiration of twenty-three minutes, the explosion took place."

It has never been ascertained just how many bombs were launched in this way, but the fact that these pioneering tests were carried out a half century before powered flight was achieved demonstrates a strong military interest in this type of technology.

Although the event was largely ignored by the West at the time, the combination of technological innovation during the Industrial Revolution, and the advent of global conflict in 1914 provided a huge stimulus to the innovation of unmanned aerial vehicles.

According to the Imperial War Museum in its "Brief History of Drones:"

"The first pilotless vehicles were built during the First World War. These early models were launched by catapult or flown using radio control. In January 1918, the US Army started production of aerial torpedoes. The model that was developed, the Kettering Bug, was flown successfully in some tests, but the war ended before it could be further developed."

Further developments of the technology occurred during the period between the wars with the first use of the word "drone" appearing to make its way into the lexicon in around 1935.

The use of drones for reconnaissance missions was extensive during the Vietnam War, and this period occurring contemporaneously with the Space Race, saw a rapid expansion of research in this area.

The British Imperial Museum explains the acceleration of drone development in the following fashion.

"Drones now have many functions, ranging from monitoring climate change to carrying out search operations after natural disasters, photography, filming, and delivering goods. But their most well-known and controversial use is by the military for reconnaissance, surveillance and targeted attacks. Since the 9/11 terrorist attacks, the United States in particular has significantly increased its use of drones. They are mostly used for surveillance in areas and terrains where troops are unable to safely go. But they are also used as weapons and have been credited with killing suspected militants."

The late 20th century saw rapid technological development in drones, and the beginning of their commercial and personal use, rather than remaining a military technology. The emergence of civilian usage and its rapid adoption in Australia can be shown through the introduction of rules for drone piloting in 2002 by the Australian Civil Aviation Safety Authority (CASA) (https://www.gizmodo.com.au/2018/07/10-laws-for-flying-drones-in-australia/).

As we approach the end of the second decade of the 21st century it is clear that the application of drones has moved far beyond its military origins. This has huge implications for many industries including the Not for Profit and the Community Service sector, essentially any operation where aerial vision or transportation of items is required and is otherwise unable to be achieved due to the cost probative nature of larger manned aircraft. It is against this background of emerging technologies that Surf Life Saving New South Wales (SLSNSW) is seeking to innovate and adapt. Our aim is to utilise drone technology to help us achieve our most essential aim of protecting the lives of those who seek to enjoy our coastal assets. "Eyes in the sky" is a new asset Lifesavers can utilise to extend their capabilities.

During the 2017-18 patrol season, Surf Life Saving NSW began operating Unmanned Aerial Vehicles (UAVs) in a trial funded by the NSW Department of Primary Industries (DPI). Volunteer Lifesavers and Lifeguards completed more than 2600 flights across nine locations on the North Coast between 15 December 2017 and 30 April 2018, identifying marine creatures including sharks, dolphin, bait balls and rays as well as rip currents and other coastal hazards. This trial and other operations being conducted by Surf Life Saving NSW have led to us investigating the

key question of how best to evaluate the potential of this technology in protecting coastal communities from harm?

The trial indicated that aerial surveillance provided by UAVs can be highly effective at identifying hazards such as sharks. Notwithstanding the primary function of the DPI trial was data collection related to the presence of sharks and various shark species and size, the use of drones in daily operations creates the potential for this information to then be used by Lifeguards and Lifesavers to alert swimmers and surfers of an immediate threat to their safety. It also provides an opportunity for swimmers in distress (ie not shark related) to be located and floatation devices deployed.

In January 2018 Surf Life Saving NSW was involved in a world-first. Two lives were saved when a rescue pod (ie a floatation device) was dropped from a UAV to swimmers in distress on the north coast of NSW (Lennox Head), inflating on impact and resulting in a successful rescue. The aerial vision 'went viral' and the rescue was viewed more than 10 million times, around the world.

Our quantitative research has certainly indicated that a tipping point has been reached regarding community acceptance of drone technology. Surveys of beachgoers on the North Coast indicated 96% of people felt safer at a beach with drone surveillance, and 81% strongly agreed that drones increased lifesavers' ability to spot rips and other hazards. 94% of beach users would like to see more drones on NSW beaches.

Looking at the results of the trial and identifying challenges to be met in future, what are the issues around the use of UAV technology in lifesaving and hazard identification? How should this technology integrate with existing lifesaving assets and networks including council lifeguards? Can the implementation of UAVs provide a low cost solution to protect coastal users? What part do land managers play in leveraging the potential of UAV applications?

Surf Life Saving in NSW

In order to deliver a professional water safety service to the millions of beachgoers who venture to the coast each season, Surf Life Saving NSW via its 129 clubs allow access to specialist surf rescue gear and equipment for use by our patrolling volunteers. Extensive training and updating is undertaken annually by our volunteer workforce to ensure they are well equipped to utilise the latest and most appropriate rescue methods and equipment as it relates to each individual rescue situation or location.

New South Wales boasts a coastline stretching over 1,700 kilometres, there are over 800 accessible beaches and 300 rock platforms for people to enjoy. With such a huge area to cover it is important to ensure that our assets are strategically placed to ensure that there is strong coverage in the most heavily frequented areas.

A glance at the nature of our membership reveals an organisation that encompasses a broad cross-section of the community. Surf lifesavers come from all walks of life and occupations, of our 74,000 members around 21,000 are on active patrol duty throughout the season, as well as several thousand "rookies" or junior lifesavers who are in training for their full qualifications.

With the patrol season extending between September and April annually, ensuring our volunteers are equipped to do what they do best requires a significant and ongoing investment. It costs approximately $60,000 to purchase the required gear and equipment to establish a modest patrolling service from start-up, and there are many ongoing costs related to maintenance and replacement, as well as a significant investment in both money and time to ensure our members have access to the best possible information and skills.

Serving Our Community

The Surf Life Saving movement in NSW has a long and distinguished history dating back to the early years of the twentieth century.

It has entered folklore that swimming in daylight hours was outlawed by the establishment, and it wasn't until it was challenged in a very public manner by Mr William Gocher at Manly Beach in September 1902 that changes began. Along with others, whose names have been lost to history, Gocher's example helped create the movement leading towards social change. What quickly became apparent as more and more people entered the ocean was that Australians lacked the necessary skills to survive in this new environment.

From these humble beginnings the Surf Life Saving movement was born and from the start has been community oriented, with a focus on preventing loss of life.

Though the equipment in use at the time can best be described as primitive, the volunteer ethos and dedication of lifesavers has always been strong.

Rescue equipment plays an important role in keeping beachgoers safer, and Surf Life Saving NSW is now preparing to meet the technological challenges involved in keeping Australia's coastal users safe.

New South Wales Shark Management Strategy: Remotely Piloted Aircraft Systems (RPAS) for bather protection on NSW coastal beaches

Overview of Shark Surveillance

Shark bite occurrences are uncommon; however, they are highly traumatic for the people involved. These incidences often attract disproportionate media attention and promote public fear, leading to a demand for improvements to beach safety by means of shark bite mitigation strategies.

In New South Wales, Australia, an increase in beach visitation for recreation has coincided with an increase in reported incidences. Such shark bite incidences have attracted disproportionate media attention and promoted public fear, often further skewing the levels of perceived risk amongst the public. Consequently, in the last few years, there has been a rapid increase in public demand for more bather protection measures to be implemented, not just in northern NSW, but elsewhere along the coastline of NSW. There is a need for effective and reliable systems that address beach safety with regards to shark bite incidences to appease this public concern, which has been shown to affect local communities in many ways.

Conversely, public opinion is divided around the culling of sharks and the effects on other marine life when mitigation strategies such as nets are utilised, hence making these approaches often unpopular.

The SLSNSW pilot program is collecting data to assess the long term viability of using drones for shark mitigation. Part of the research is understanding the reliability of drone pilots in the identification of sharks (as opposed to other marine species), and specifically, those that pose an immediate risk to swimmers/surfers. Pilots record sightings and DPI scientists then verify these against actual footage captured by the drone's camera's which is downloaded post flight.

Aims:

The aims of the pilot project are to:

- Continue successful drone surveillance operations in the interest of public safety.
- Build upon existing 'best practice' and surveillance procedures.
- Continue research regarding near-shore shark behaviour to allow more informed management decisions regarding drone surveillance operations.

- Continue assessing the effectiveness of shark evacuation procedures initiated by a drone sighting.

Materials and methods

Operating drones on a scale larger than personal use necessitated Surf Life Saving NSW operating under the Civil Aviation Safety Authority (CASA) regulations. The regulations are extensive and relate specifically to public safety, they are the same basis of regulations that manned aircraft operate under. In phase one of the pilot program, Surf Life Saving NSW used a third party provider approved to conduct operations under these regulations.

In the second phase of the pilot, Surf Life Saving NSW has obtained its own Remote Operators Certificate (ReOC) from CASA and has employed a Chief Pilot. This has required an extensive development of Standard Operating Procedure (SOPs) for the operations, these all being part of the assessment and approval process undertaken by CASA.

The challenge for the organisation initially has been addressing the extent of coverage and the number of pilots required to be trained in both drone flying and marine life identification. To that end a purpose built management software is utilised to manage both risk and maintenance requirements for the equipment.

CASA regulations delineate between what are known as Restricted Category (ie their total weight is below 2kg) and larger aircraft. The cost differential between the two categories of aircraft is significant both in terms of equipment and training/licensing of pilots. A sub 2kg unit (eg a DJI phantom IV) costs approximately $2,000 as opposed to a larger unit capable of carrying a rescue pod (ie an M600) at over $10,000. Additionally training/licensing necessary to fly the larger unit can cost upwards of $3,000 and a week of time.

Licencing requirements are different for the Restricted Category, however, there are particular locations where full licencing is required due to the airspace being restricted (eg military airspace, proximity to airports etc). On the basis of the scale of the Surf Life Saving operation, sub 2kg drones have been utilised to enable a more cost effective and agile deployment, notwithstanding in the first year of the pilot, the smaller aircraft were unable to carry additional features aside from a camera.

Initially, it was only possible for drones in the larger category to be equipped with rescue floatation pods and sirens (to alert swimmers of danger). Within the first 12 months of the trial, technological advances have seen both feature now in final stages of prototype development for use with sub 2kg drones. What this means for Surf Life Saving, is that each drone utilised for the shark surveillance program, can also be a tool for broader lifesaving capability thus making them equipment of choice.

Speed, altitude and flight path

During each flight in the NSW DPI drone experimental trials, the DJI Phantom 4 drone was expected to be flown at 8 m/s (**29 – 30 km/h**) and at an altitude of **60 m** with the camera at nadir (pitched 90 degrees to face downwards). This gave a search width of approximately 110 m.

Flights paths are designed as a transect, with the inside edge of the viewable area lining up with the ‘backline’ of the surf break. The position of the surf break is likely to change significantly due to tide and weather variables, so the flights were to be conducted with manual control (as opposed to automated flight paths) using the DJI Go4 app.

Each flight path extended up to 1 km north and south of the ground control station, covering a 4 km flight circuit. During poor visibility conditions, which restricted line-of-sight distances regarding the drone, transect length occasionally required shortening to maintain CASA protocols.

Times and Locations

For the 2018/19 season, Surf life Saving NSW and NSW DPI have agreed on specific locations and times to conduct coastal surveillance flights.

Region 1				
Kingscliff **Main Beach Byron Bay** **The Pass*** **Suffolk Park*** **Lennox Head** **Sharpes Beach*** **Lighthouse/Shelley Beach Ballina** **Evans Head**	SPRING PRE-SUMMER INTERIM SUMMER PRE-AUTUMN INTERIM AUTUMN	20/09/18 – 15/10/18 16/10/18 – 30/11/18 1/12/18 – 29/01/19 30/01/19 – 30/03/19 1/04/19 – 29/04/19	LG's & VOLS VOLS LG's & VOLS VOLS LG's & VOLS	7 Days Weekends 7 Days Weekends 7 Days
Region 2				
Yamba	PRE-SUMMER INTERIM	1/11/18 – 19/12/18	VOLS	Weekends
	SUMMER	20/12/18 – 29/01/19	LG's & VOLS	7 Days
Woolgoolga	PRE-AUTUMN INTERIM	30/01/19 – 12/04/19	VOLS	Weekends
	AUTUMN	13/04/19 – 29/04/19	LG's & VOLS	7 Days
Region 3				
Tacking Point	SPRING	29/09/18 – 15/10/18	LG's & VOLS	7 Days
	PRE-SUMMER INTERIM	16/10/18 – 19/12/18	VOLS	Weekends
	SUMMER	20/12/18 – 29/01/19	LG's & VOLS	7 Days
	PRE-AUTUMN INTERIM	30/01/19 – 12/04/19	VOLS	Weekends
	AUTUMN	13/04/19 – 29/04/19	LG's & VOLS	7 Days
Region 4				
Birubi	PRE-SUMMER INTERIM	1/11/18 – 19/12/18	VOLS	Weekends
	SUMMER	20/12/18 – 29/01/19	LG's & VOLS	7 Days
	PRE-AUTUMN INTERIM	30/01/19 – 12/04/19	VOLS	Weekends
	AUTUMN	13/04/19 – 29/04/19	LG's & VOLS	7 Days
SMP				
Redheadb	PRE-SUMMER INTERIM	1/11/18 – 19/12/18	VOLS	Weekends
	SUMMER	20/12/18 – 29/01/19	LG's & VOLS	7 Days
Avoca	PRE-AUTUMN INTERIM	30/01/19 – 12/04/19	VOLS	Weekends
	AUTUMN	13/04/19 – 29/04/19	LG's & VOLS	7 Days
Region 5				
Kiama	PRE-SUMMER INTERIM	1/12/18 – 19/12/18	VOLS	Weekends
Mollymook	SUMMER	20/12/18 – 29/01/19	LG's & VOLS	7 Days
Region 6				
Pambula	PRE-SUMMER INTERIM	1/12/18 – 19/12/18	VOLS	Weekends
Tathra	SUMMER	20/12/18 – 29/01/19	LG's & VOLS	7 Days

2 x 20 minute flights are to be conducted every hour. This is an increase from the single flight per hour conducted in 2017/18.

- Weekday flights are to commence at 0730 and conclude at 1530
- Weekend flights are to commence at 0900 and conclude at 1600

If a shark is sighted or another situation required a flight sooner, then situational adjustments can be made.

Shark Procedure

All shark sightings seen by SLSNSW drone pilots are filmed. Shark video data is used for behavioural and abundance analysis by NSW DPI research. If a shark is sighted video is immediately recorded and the drone lowered to a height of **15 m.** The sightings are to be reported on an online group established for the NSW DPI Drone Trials, so the NSW DPI coordinators are immediately aware. When reporting shark sightings, pilots use the following examples as a template: “NSWDPI Drone report 3 m white shark 300 m north of Lennox Head surf club, tracking north. No water users nearby, no threat.” or “NSWDPI Drone report 3.5 m unknown shark at Ballina North Wall, tracking north. Water users evacuated, authorities notified.”

Hazardous sharks are defined as a Bull, White, Tiger, or unknown (unidentifiable) shark greater than 2 m.

If a hazardous shark is sighted, pilots record video and lower the drone to 15 m (where a size estimate can be obtained), and then track the shark until a drone battery change is necessary or the shark moves on to deeper water or beyond line-of-sight limitations.

If the shark is sighted to be within 100 m of water users, or 200 m of water users and swimming towards them, pilots activate evacuation procedures. Where public safety becomes a concern, pilots break shark tracking procedures to change orientation as required or leave the shark to alert water users.

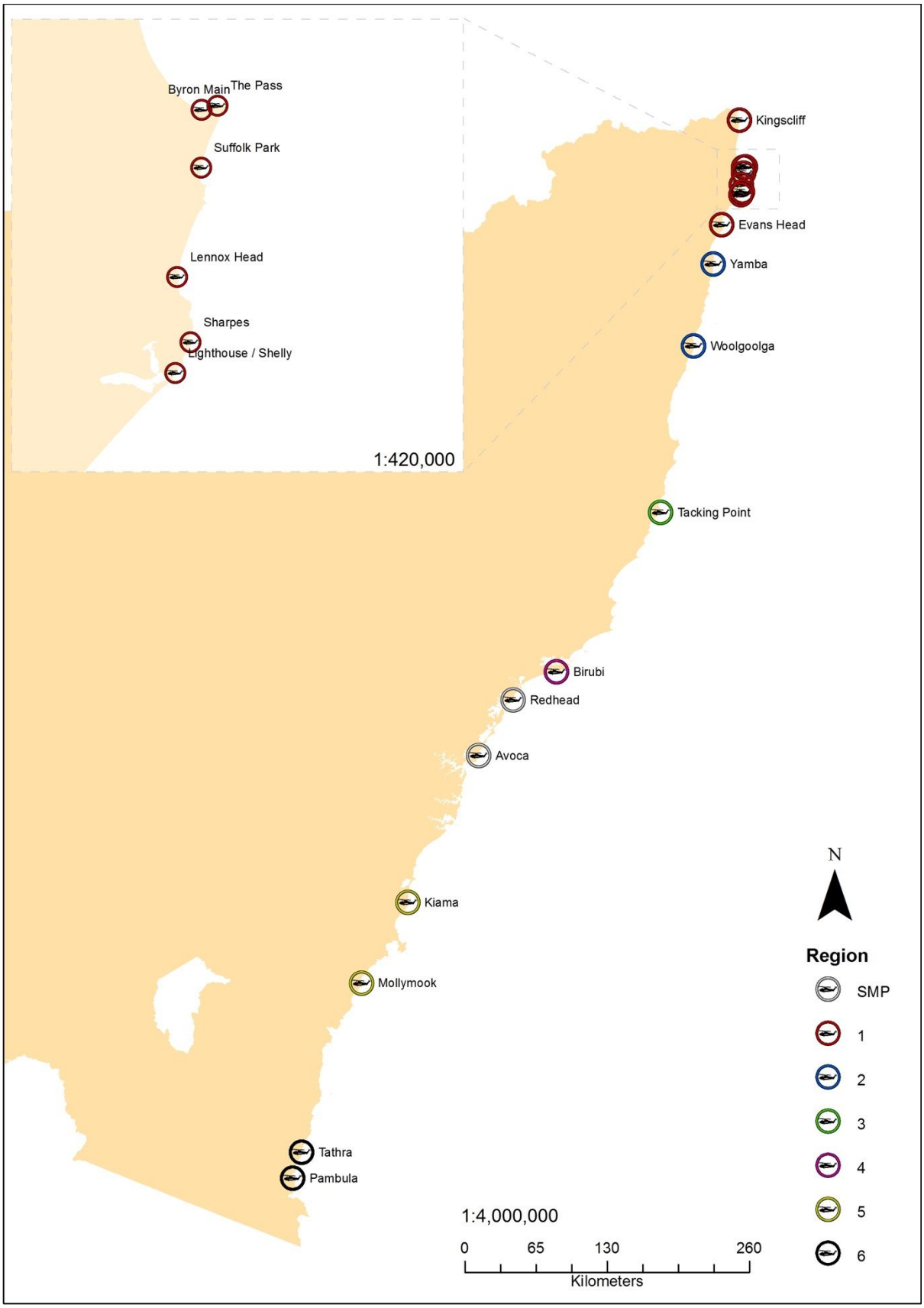
Shark alarms fitted to the drones are then activated and the shark tracked. Each pilot also has an air horn on their person to also utilise to aide in evacuation (or the failure of the drone siren). Additionally where readily accessible a surf club siren is used.

Administration

All UAV pilots are required to complete data sheets associated with each flight. This includes flight data, weather variables, and animal sightings. If a flight is cancelled, the time the survey is due to start is written in the ‘start survey time’ field and the reason for cancellation was stated in the comments. Most common reasons for cancelled flights are rain and strong wind (>20 knots). This data is collated as part of the pilot project and helps to inform both the DPI in terms of the gross number of sightings against the total flight hours, and also assists Surf Life Saving NSW to assess the suitability and robustness of the aircraft for the purpose of Surf Life Saving.

Moving into phase 2 of the pilot, Surf Life Saving is investing heavily in more automated and integrated data collection systems to make the reporting tasks easier for pilots (most of whom are volunteers and operate less regularly than a professional paid operator would do).

This map of the NSW Coastline indicates where drones will be operating during the 2018/19 patrol season.



The following summary statistics have been collected as part of phase one Drone trial in operation at 9 locations at the Far North Coast (FNC) in the 2017/18 season. (Dec 2017 to April 2018).

DESCRIPTION	DATA TOTALS		
Flight Summaries:	**TOTAL**	**Previous Period**	**Current Period**
Total flight time hrs	685	88:32	174
# of pilots	146	12	36
# of flights to date	2639	363	754
# of flights prevented by weather (wind velocity/Rain)	927	135	371
# of flights prevented by proximity (Crowds/People)	203	4	48
# of flights prevented by pilot knowledge transfer process	104	14	14
# of Flights prevented - no reason given	75	0	25
# of Flights prevented – equipment issue	61		61
Observation Summaries:			
# of RIPS Identified	731	116	237
# of Dolphin Pods	233	49	82
# of Turtles	52	7	33
# of Rays	139	17	34
# of Whales	1	0	1
# of Bait Fish Clusters	36	5	11
# of Shark - Hammerhead	0	0	0
# of Shark - White	2	0	2
# of Shark - Whale	3	2	0
# of Shark - Bull	1	0	0
# of Shark - Tiger	2	2	0
# of Shark - Unknown	34	0	14
# of Unidentified	9	9	0
Interactions/Actions Taken:			
# UAV Responses	20	9	2
# of Water Evacuations	15	2	2
# of UAV Rescues	1	0	0
# of Positive Feedback Comments (Public)	363	24	200

Challenges For The Future

To get to the point where we are making regular drone flights throughout the 2018/19 patrol season has been an extended process. Surf Life Saving NSW has been researching the potential of drone technology for several years and has been involved in multiple trials during that time.

As a lifesaving organisation it is imperative that we utilise technology to its full potential to help with our core focus of preventing loss of life on the beach.

Over 110 years of history, Surf Life Saving has regularly introduced new rescue equipment into its arsenal. From the humble reel to jet skis, and the iconic inflatable rescue boat, each change and innovation represents a commitment to excellence.

A fundamental challenge in an organisation of our size is the diverse opinions within the membership. New technologies require time to integrate into our operations and it remains important to bring the members along for the journey. That said, anecdotally there has been overwhelming acceptance and enthusiasm for the use of drones in Surf Life Saving by the membership.

One of the key advantages of introducing drones to our organisation is the opportunity to engage and reach different segments of the membership. Many lifesavers across a broad range of ages have a passion for technology outside the beach environment and learning to pilot drones provides a pathway for continued involvement in the organisation. Indeed the opportunity exists to attract people not currently engaged with the movement into this specific area of operations.

Again, the breadth of our operations across the entire length of the NSW coastline, across 129 clubs, will be challenging with respect to drone use. The regulatory environment is such that operations from training through to flying, need to be centrally managed and is at a higher level of compliance than required in the marine environment with respect to motorised craft (ie Inflatable rescue boats used at each club). To achieve this in a future state where each club has its own drone, as it does an IRB will be challenged due to this overlay. Technology will assist in that management.

Costs are another consideration in this future state. The current program is funded via the DPI with the outcome related to shark surveillance and research (as well as the piloting of the technology more broadly for surf lifesaving operations). Only selected sites are operational, and those are fully funded under the pilot. Where clubs are required to purchase their own equipment at approx. $5,000 for a complete kit with ancillary equipment plus training costs, this can become cost prohibitive. Similarly the equipment's lifespan is somewhat limited with between one and three seasons considered operational, depending on the usage. Potential commercial partnerships and the decrease in the cost of the technology over time may assist a broader roll-out in the future.

Conclusion

As discussed previously, drones have enormous potential within the Surf Lifesaving movement.

At present they are playing a crucial role in surveillance of sharks (including identifying species) but they can play a larger role.

It is important to note that they are not considered to be a replacement for active frontline volunteer lifesavers, however they are a complementary tool that can used to assist in operations such as search and rescue or water safety in large events including surf carnivals and ocean swims.

Surf Life Saving NSW believes that the emerging technology of drones will continue to form part of overall lifesaving strategies, and is committed to working with our clubs and branches to integrate it into the important work that our members do on the beach each season.

Steven Pearce AFSM – CEO Surf Life Saving NSW

Steven was appointed CEO of Surf Life Saving NSW in 2017. He has 32 years' emergency management experience with Fire and Rescue and NSW SES, where he coordinated whole of government responses to major natural disasters and emergencies. Steven's focus is on transformational change, through innovation, collaboration and technology.