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AVIAN ANTI-SUBMARINE WARFARE PROPOSALS IN BRITAIN, 1915-18: THE ADMIRALTY AND THOMAS MILLS

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Abstract

Attempts were made throughout the First World War to discover means of countering the enemy submarine. Both defensive and offensive measures were assessed and sometimes implemented, with varying degrees of success. So serious were the loss caused by the U-boats in their campaign of unrestricted warfare and the resulting effect on national morale that the authorities in Britain were soon prepared to consider from all quarters every proposal to locate, track, destroy, neutralize or evade the U-boat. Systematic assessment and experiment began in 1915 with the establishment of the Board of Invention and Research (BIR), and then continued in late 1916 with the creation under naval control of the Anti-Submarine Division (ASD). To develop anti-submarine measures, as well as others to contribute to winning this 'struggle of invention', the BIR invited and received suggestions from scientists, naval personnel and members of the public. The latter source produced many bizarre ideas, but some of them were considered worth investigating. Among these were proposals to train gulls and other birds to indicate the presence of U-boats.[1] In this paper, the historical and organizational context of the investigations is discussed before an examination is made of the proposals themselves.

Introduction

A matter of very grave concern soon after the beginning of the First World War was the disastrous effect of the depredations of U-boats, whose large-scale and seemingly irresistible destruction of merchant shipping caused not only great loss of life but also a fear that a nation of 45 million, which had possessed in 1914 approximately half the world's merchant tonnage, would be fatally starved of materials and food. Desperate attempts were made to find reliable means of locating U-boats for destruction, and because of the seriousness of the threat, all manner of possibilities were considered. However, no solution was found until, with the entry into the war of the United States in April 1917, sufficient numbers of destroyers were made available to test and confirm the effectiveness of the defensive convoy system.

The U-boat campaign represented an effective type of early psychological warfare which was based on the scientific and technological success of the enemy. It was in

these circumstances that the British government decided to attempt a response through a programme of secret research part of which depended itself on psychology and the effective control of behaviour - that of the seagull and sea lion.[2] To meet other wartime requirements, the use of 'sniffer dogs' and carrier pigeons was already established, quite well known to the public, and the result more of simple training than applied science. The new research would bring together scientists, naturalists, circus-trainers and sceptical naval officers, but the scientists represented other disciplines than animal psychology, and there is no evidence that any of the few British animal psychologists who could have offered useful advice were appraised of this secret programme or approached for assistance.[3] After the end of the war, the manipulation of the behaviour of animals for military purposes was neglected in Britain but developed in the United States, where the principles of behaviourism were found to be most appropriate and applied to procedures such as the guidance of missiles by pigeons which had been subjected to operant conditioning, and the detection of submerged objects by sea lions and dolphins.[4]

The U-boat crisis

By late 1916, Jellicoe recognized 'a serious danger that our losses in merchant ships, combined with the losses in neutral merchant ships, may, by the early summer of 1917, have such a serious effect upon the import of food and other necessaries into the Allied countries as to force us into accepting peace terms which the military position on the Continent would not justify, and which would fall short of our desires.'[5] He considered U-boats 'the most serious menace with which the empire has ever been faced.'[6] Beatty saw the danger at that time as 'jeopardising the fate of the nation and seriously interfering with the successful prosecution of the war'.[7] An Admiralty official memorandum to the Government admitted: 'Of all the problems which the Admiralty have to consider, no doubt the most formidable and the most embarrassing is that raised by submarine attack upon merchant vessels. No conclusive answer has as yet been found to this form of warfare; perhaps no conclusive answer ever will be found. We must for the present be content with palliation.'[8]

The development of the successful U-boat campaign against commerce in the second half of 1916 had been a logical strategic response, since

> After the battle [Jutland], as before it, we strangled German supplies by means of our agreements with neutrals, our economic strength, and our intercepting cruiser squadrons [and] the German Naval Chiefs had been instantly compelled to realise that if Great Britain was to be overthrown at sea, the blow must be struck, not by the High Sea Fleet, but by the submarines.[9]

Supported by the army high command, as well as the press and public, Admiral von Holtzendorff, Chief of the Naval Staff, then urged unrestricted submarine warfare.[10] By January 1917 German civilians were facing starvation as a result of the successful blockade of their ports,[11] and the war on land had reached stalemate. It was thought that an unrestricted campaign could return the compliment of crippling shortages with a conclusive effect, promising a quicker victory, in the meantime instilling what Holtzendorff described as 'the psychological elements of fear and panic'. At the time

of its announcement in February the Germans hoped, and Jellicoe and others believed, that unrestricted submarine warfare, resulting in sinkings of at least 600,000 tons per month, could force Britain to make peace by the following October. America's entry into the war (6 April 1917) because of the new campaign, was both envisaged and considered a risk worth taking, since the introduction of properly prepared land forces into the continental theatre would be too late to affect the anticipated outcome a few months ahead. According to Admiral Müller, Chief of the Naval Cabinet, this decision was the 'last shot in our locker'.[12]

Fig 1. Admiral Henning von Holtzendorff. Photograph courtesy of Bibliothek für Zeitgeschichte, Stuttgart.

Losses of British, neutral and allied mercantile gross tonnage from submarine and (to a much lesser extent) mine attack had steadily risen since July 1916, when the figure was 110,757 tons. By October it was 352,902 tons, then in February 1917, 500,573 tons (of which 256,000 were British losses from submarine attack only), and in April, 870,359 tons (513,000).[13] At the end of April, Sir Leo Chiozza Money, Parliamentary Secretary to the Ministry of Shipping, estimated that, after allowing for replacements, the 8,394,000-odd tons of shipping in the import and export service of Britain would probably be reduced to 4,812,000 at the end of the year, allowing for no logistical or trade use but only emergency food supplies.[14] By February 1917, 140 U-boats were available for use in home waters. Approximately 8 U-boats a month were being added in 1917, while British production of destroyers was only 4-5 per month maximum, and of submarines, two per month. No increase in output of destroyers was possible for the 15 months ahead, because at least 15 months was the time taken to build one (in Germany it was 12 months). British submarines took up to two years to build, German as little as six months. Finally, the construction rate of British merchant ships was also slow. Only 22 U-boats had been sunk in 1916, mostly when working on the surface. Trawlers were too slow to engage them, and motor launches needed good weather and to be near the coast. Jellicoe was reluctant to spare destroyers in early 1917 because of a shortage of depth-charges and the absence of an effective submarine detection device.[15]

After America entered the war, a new supply of destroyers was made available, and the development of the convoy system of protection became possible.[16] Rear Admiral Sims, commander of the American naval forces, described the successful arrival of an experimental convoy on 20 May 1917 as 'one of the great turning-points of the war'.[17] Convoys led to an increased use of depth-charges by escort vessels, and as the rate of U-boat successes began to decline after August 1917 the original expectations of the German leadership were eventually confounded. Meanwhile, Holtzendorff rejected a promising modification of German tactics to deal with convoys, suggested by Kommodore Hermann Bauer. This was later used in the Second World War as the system of wolf-pack with directing mother ship.[18]

The Board of Invention and Research, national morale and public involvement

Established by A.J. Balfour in July 1915 and gradually to dissolve after September 1917, the role of the Board of Invention and Research (BIR) was to evaluate problems, propose solutions and organize research schemes, at the same time sifting, assessing and, as appropriate, developing the inventions and ideas of others. Section II[19] eventually received by far the largest government grant.

There were, from the start, tensions between the Royal Navy and civilian science, exacerbated by the BIR's independence from naval control, by the abrasive character of the Chairman of the BIR, Lord Fisher, who was not universally liked in the Royal Navy and who wanted to exert an influence in the conduct of the war, and by the reluctance of the Royal Navy to countenance involvement by civilians in the solution of problems it saw as its own responsibility. Accordingly, Jellicoe as Commander-in-Chief of the Grand Fleet had written to the Admiralty on 29 October 1916 advising further, Royal Navy oriented, organization against the submarine threat,[20] and on 10 December 1916 Professor W.H. Bragg of Section II complained to Sir J.J. Thomson

(one of the Central Committee of the BIR): 'We are practically cut off from all contact with the navy, except such part of it as is hostile to BIR.'[21] That month the organization of anti-submarine work was improved by the creation of the Anti-Submarine Division (ASD) under the direction of Rear Admiral A.L. Duff.[22] Jellicoe later reflected that the ASD 'received much valuable assistance from the great civilian scientists who gave such ready help during the war, the function of the naval officers working with the scientists being to see that the effort was being directed along practical lines'.[23]

Fig 2. Admiral A L Duff with (left to right) Admiral Benson USN, Mr Daniels and Sir Eric Geddes. Photograph copyright and courtesy of the Imperial War Museum, London. Negative number Q19398.

By April 1917 'The most popular game on both sides of the Atlantic was devising means of checking the underwater ship. Every newspaper, every magazine, every public man, and every gentleman at his club had a favourite scheme for defeating the U-boat campaign.'[24] Nearly 13,000 British lives were eventually lost because of U-boats, and in April 1917, one ship out of four that left the UK never came home. Concerning such losses, the government was driven to publish false shipping returns of entries and sailings, so that this disguise might avert public panic.[25]

The problem of maintaining national morale was made difficult by the level of public anxiety and frustration resulting from large-scale U-boat successes.[26] The submarine as a modern weapon was proving itself for the first time, and in its sinister way

represented a triumph of new technology and ruthlessness over the accepted traditions of conflict at sea. The *Titanic* disaster was fresh in people's minds when the *Lusitania* was torpedoed, so that the horrors of destruction of large surface vessels and their occupants by hidden dangers of the deep became a morbid obsession. The Press was, of course, visibly restless and disturbed, too, and both the Government and the Naval High Command were criticised.[27] After the failure early in the war of the Channel boom defence, reliance had next been placed on mines and on an auxiliary coastal yacht and motor-boat patrol under the command of Admiral Sir Frederick Inglefield, before his retirement in 1916 at the age of 61, when operations at sea then became co-ordinated by the newly formed ASD. This patrol has been described as ineffective and ludicrous. Only one in ten of his vessels were (lightly) armed; one in 85 had wireless; and there were too few to patrol vast areas. To deal with a submarine on encounter, 'teams of two swimmers were organized in each motor launch. One man carried a black bag, the other a hammer. The plan was that if a periscope was sighted, the launch would cruise as near to it as possible, then the swimmers would dive in, seize the periscope, and after one man had placed the black bag over it, the other would attempt to shatter the glass with the hammer. Inglefield's other brain child was to attempt to train seagulls to defecate on periscopes, and for a short while a remote corner of Poole harbour in Dorset was littered with dummy periscopes and hopefully incontinent seagulls.'[28]

Fig 3. Admiral Sir Frederick Inglefield, when Rear Admiral in command of the 4th Cruiser Squadron, 1907. © National Maritime Museum, London. Negative number P6010.

In these circumstances the creation of the BIR may have been a mixture of propaganda and expediency.[29] Scientists were publicly pressing the Government to make better use of their talents, while figures like H.G. Wells emphasised that the war was essentially a 'struggle of invention'. It was clearly necessary, if only for the sake of national morale, that the Government reassure the public, through the establishment of an organization like the BIR, that all opportunities were being exploited, especially to overcome the U-boat. During the course of its existence the BIR received and assessed over 37,500 suggestions and inventions from the general public, of which about 14,000 concerned submarines, anti-submarine measures and wireless telegraphy.[30]

These suggestions, many received and redirected by the naval authorities, varied considerably in value, and only a few were acted on. (Beatty had also earlier encouraged his officers and ratings to submit ideas, which might earn a reward, but there were no workable results.) Suggestions from all sources were categorized into 'Proposals by Officers of the Fleet'; 'Device and suggestions from the Admiralty', for example the use of cork float lines, dummy submarines and explosive chain trawls; and 'Suggestions by arm-chair critics', such as that from a Surrey farmer on 28 April 1917 to send out small armed boats protected with a three-foot-thick layer of pressed hay padding along the side, covered in painted canvas.[31] It was suggested to Section II of the BIR that specially selected strong swimmers be armed with sharp pointed hammers with which to pierce the hull of a hostile submarine;[32] or that green paint poured on the sea could obscure enemy periscopes and make a U-boat commander fatally confused about his depth. Another suggested that the dangers of a bright, moonlit night could be reduced by training a circle of 24 searchlights at the moon itself, throwing black or dark-tinted rays. As a change from frequent recommendations concerning the use of strong magnets to transfix the U-boats, in 1917 a gentleman advised Jellicoe that in order to expose enemy submarines barrels of Eno's Fruit Salt should be placed in strategic positions on the bottom of the North Sea: when the presence of U-boats was suspected the barrels would be opened by remote control from points ashore and the vessels would surface involuntarily on a mass of effervescing bubbles, then to be despatched by gunfire. On one occasion a psychic was permitted to enter the Admiralty's submarine tracking room but failed to locate any U-boats by dangling her threaded needle over charts of the Atlantic,[33] while remote dowsing was suggested by Sir William Barrett, supported by the BIR's own psychically-inclined Sir Oliver Lodge.

The introduction of the convoy system in 1917 and the development of ASDIC shortly afterwards meant that the seagull proposals appeared especially obsolete only a short time after they had been considered, and although assessed in conditions of secrecy, public references to the proposals were permitted by the censor from 1918. The decision to turn to seagulls and, in a more extensive series of trials, to sea lions, was no doubt prompted by the slow and uncertain progress with more conventional anti-submarine measures. Work on the hydrophone, begun in 1915, continued all the while, but it was relegated as surely as the seagull and sea lion as soon as convoys proved their worth and when ASDIC arrived.

The seagull proposals

Between 1915 and 1917, the BIR considered the use of gulls and other birds to indicate the presence of U-boats, and from early 1917 until the end of the war the idea was energetically promoted by Thomas Mills, who had emigrated to Australia in the early 1860s and returned to England in the mid 1880s, having made his fortune as a gold mine pioneer and owner in Queensland.[34] The BIR eventually commissioned trials in summer 1917, but then decided to abandon the possibility. It had not invited Thomas Mills to participate as an adviser, while in the case of the sea lion trials, 'Captain' Joseph Woodward was commissioned to work with his music-hall animals under the supervision of BIR scientists. Woodward's skills were unique, and necessary to the practical trials, but the idea shared with Mills did not require the latter's participation in a test: W.H. Hudson and Richard Kearton were instead consulted as specialists in bird behaviour. The BIR continued to be lobbied by Mills, who carried out his own trials at his own expense, and who became increasingly exasperated at the BIR's reluctance to continue to consider a scheme which had become an obsession with him.

The Admiralty and the BIR had received suggestions to train gulls to detect periscopes in 1915 but the matter was not taken further until raised again and referred to Rear Admiral A.L. Duff, Director of the Anti-Submarine Division, in late 1916. It was proposed that merchant ships should tow a dummy periscope 'from which at intervals food would be discharged like sausage-meat from a machine' to teach the birds to associate periscopes near ships with food, leading them to swoop on the periscopes of real submarines. Dr Chalmers Mitchell (Secretary of the Zoological Society of London) and Sir Charles Parsons of the Central Committee of the BIR were keen to try the scheme, but Duff was concerned that it could result in many scares.[35] (It is probable that Duff had little time for this proposal, and he later expressed anger at the BIR's parallel work with sea lions.[36]) Commodore Hall told the Sub Committee that the idea had often been considered and that in the previous autumn he had been instructed to prepare plans for the occasional discharge of fish from the torpedo tube of a submarine to ascertain bird attentiveness, but the matter had not been progressed. He felt it might be difficult to imitate the true appearance and steady movement of a periscope, and that captains might come to rely too much on gulls, the watch kept on merchant ships being in any case 'very bad'. Another commentator also pointed out that gulls are not found very far out at sea.[37] However, the Sub Committee decided that a trial feeding mechanism should be devised.

At the meeting of the Central Committee of the BIR on 10 May 1917, presided over by Lord Fisher, it was reported: 'In consequence of a suggestion made by the Board of Invention and Research to test the possibilities of attracting seagulls to the periscopes of submarines by ejecting food therefrom and thereby training them to follow and locate enemy submarines, the Admiralty have approved an experiment being made in [submarine] B3 and have asked BIR to provide a suitable food box for the purpose'.[38] During the Sub Committee meeting of 22 and 23 May 1917,[39] Paget as secretary reported that a Mr Carnegie was constructing an apparatus for intermittently feeding birds from a dummy periscope, to be fitted on B3 for trials in the Firth of Forth, as proposed by Commodore Hall and approved by the Third Sea Lord.[40] W.H. Hudson, the ornithologist and popular nature essayist, had been invited to assist in the experiments.[41] At this meeting the idea of using pigeons was raised: a ship could carry

and control these birds. Commander Middleton who was present added that he had had experience with pigeons on board and that they would fly around at great distances. Paget replied that this idea had been put forward before, by a Mr Kingston Clarke, but that the officer in charge of the pigeon loft at HMS *Excellent*, Whale Island, had not considered it feasible. Middleton was asked to discuss the suitability of this and other species of birds with Hudson. Soon after, at the meeting of 19 June 1917, Paget reported that a falconer had suggested the use of hawks, but after later discussions with him the idea was considered impracticable.[42]

Fig 4. Richard Kearton, emerging from camouflage. From his 'Wild Nature's Ways', London: Cassell & Co, 1903. (Cassell PLC is a division of the Orion Publishing Group, London.) Image supplied by Special Collections, J B Priestley Library, University of Bradford. (The author has endeavoured to trace the copyright holder of this illustration. If he has unwittingly infringed copyright, please contact him.)

The approved programme of experiments was placed under the supervision of Richard Kearton, who was hopeful of success,[43] but they were short-lived, and on 7 August 1917 the secretary reported to the Sub Committee that 'difficulties had arisen as to the use of B3 in these experiments, and the matter had been referred again to the Admiralty'. The Third Sea Lord soon decided that the experiments should be dropped altogether.[44] This was acknowledged at the meeting of the Central Committee on 30 August, when it was noted that Richard Kearton had been informed accordingly and

thanked.[45] The difficulties referred to may not have been technical or experimental problems, but rather those of a kind regularly experienced by civilian scientists and BIR staff when dealing with Captain Ryan, who was in charge of B3 and the Admiralty Experimental Station at Hawkcraig Point, Aberdour, Fifeshire, a Royal Navy hydrophone research and training establishment. Ryan epitomized the unco-operativeness of naval officers in business they considered the sole province of the Royal Navy, and, following his appointment to work alongside Ryan as Resident Director of the civilian scientists at Hawkcraig in 1916, Bragg had met only with frustration.[46] In January 1917 BIR research activities had then been transferred to Parkeston Quay, Harwich. Notwithstanding representation since spring, 1916 of senior naval personnel on BIR committees, tension between it and the ASD grew during 1917 and already by February the consulting panel of the BIR had presented Balfour as First Lord with a critical Memorandum concerning serious shortcomings in *Relations of the BIR with Other Departments of the Admiralty*.[47]

Fig 5. Captain C P Ryan RN, photographed between 1908 and 1911 when serving on destroyers. Photograph courtesy of Captain John Aston RN.

The Grand Fleet Secret Packs provide some indication of the inevitable failure of the intended experimentation at Hawkcraig.[48] Vice Admiral Sir Richard Peirse, who served on the Central Committee of the BIR, had contacted the Commodore (Submarines) on 17 July to report Kearton's suggestion that 'before attempting experiments with a food ejecting periscope, it would be advisable to begin with hand feeding experiments from B3'. A few days later, on 22 July, Kearton wrote to Ryan: 'I have been asked by Vice Admiral Peirse to assist you in carrying out some experiments on seagulls in connection with Submarines', adding that he would like to photograph the accomplishments. The next day, Ryan complained to the Commander-in-Chief, Grand Fleet (Admiral Sir David Beatty, who had been based at Rosyth, living in Aberdour, and who was a personal friend):

> I have the honour to transmit for your information copy of a Reference Sheet from the Board of Invention and Research, forwarded to me by Commodore (S), Admiralty, suggesting that Submarine 'B.3' be employed for training seagulls to locate submarines, with a further letter received from the expert who it is proposed should supervise this work.
> It is submitted:-
> (1) That Submarine 'B.3' is constantly employed here…[on work related to hydrophones]
> (2) That the training of seagulls would interfere seriously with this work, and that the advantages that might be gained are so extremely doubtful, that it would be inadvisable for 'B.3' to be detailed for this purpose.

Beatty replied to Ryan on 27 July, suggesting that the seagull trials should not interfere with the hydrophone work, reassuring him that B3 was still under his orders, and asking him to inform him later if co-operation with Kearton had been inconvenient. It would appear that Ryan had already decided that such co-operation would indeed be inconvenient, and no record has been found of any actual use of B3 before the decision in August to abort the project.

It is interesting to speculate on the reaction of Ryan if he had been ordered to co-operate in an extended experimental programme with Thomas Mills. Encouraged by his own observations of the behaviour of gulls in the presence of submarines off the south coast of England, Mills had sent his first letter to the BIR on 27 February 1917, when he described a method which closely resembled that later considered by Section II at its meeting of 24 April:

> Have a small float containing a dummy periscope; the float to contain a quantity of rough food, say dog or cat's flesh or any other food which will float on the water. The machine to discharge small quantities every few minutes so the birds will see the food floating on the sea. The float could be towed behind a vessel at a fair distance and made so it will sink, as when the tow-line break [to keep this secret method from the enemy]. I consider if the experiment was tried first near some port or near where the enemy submarines were working, I believe the birds in about two weeks would be thoroughly trained to fly around the periscope or over the wake of a submarine. I would suggest a small mirror or bright piece of metal

placed on top of a dummy for the first few days to attract the birds. The experiment will cost a very small sum as you have the means of carrying it out. I hope you will try it, that is, if it is not already in use. I would be very glad to give all the assistance I could or do it myself if I had the mechanical means in a suitable place and assistance from the Government, not in money.[49]

Fig 6. Thomas Mills with his wounded son, Charles, of the Australian Light Horse, at the Royal Bath Hotel, Bournemouth in April, 1917. From 'The Fateful Sea-Gull', Reading: Bradley & Son, Ltd, 1919, p. 55. (The author has endeavoured to trace the copyright holder of this illustration. If he has unwittingly infringed copyright, please contact him.)

Mills was informed in a reply simply that similar proposals had previously been considered, and there was never at any stage reference to Mills by name in BIR minutes. But he then decided to construct his own machine, having moved for medical reasons to Scotland for the more bracing climate. Clockmakers in Edinburgh and Aberdeen appeared at the same time unwilling to help build it and too curious as to the secret purpose of the machine. Mills eventually found a firm willing to start work for him. He supervised the work closely, and had to be reassured that certain visitors to the premises, looking to him like Germans or continentals, were no more than clockmakers or ice-cream vendors, and not spies.

By August 1917, when the BIR decided to end its trials with submarine B3, Mills was ready to put his machine to the test, and he successfully sought an interview for this purpose at the Royal Naval base at Granton with Admiral Sir James Starten, who then noted that seagulls would not be able to distinguish between friendly submarines and U-boats.[50] Mills was taken aback by this and subsequently advocated the retention of British and allied submarines in port, so that the use of trained gulls would not result in any mistake and because, in any case, the destruction of the U-boat (by his method) was now all that mattered. Returning south in some agitation, for patriotic reasons he declined a suggestion from a friend that his idea might be developed in the United States, but in September instead approached the BIR once more, via his lawyers, this time giving details of the machine as it had taken shape, being small and torpedo-like, weighing about 20 lbs, costing about £5 apart from the float, and able when under tow to discharge small pieces of 'tape' food in various quantities and thicknesses, at distances of up to a mile, and either near the surface or up to 100 ft below. Mills requested permission to test it and to buy petrol for the towing launch, but the BIR repeated its rejection of this method and stated its resulting inability to arrange permissions. On receipt of this rebuff, Mills approached Patent Agents and instructed them to draw up a patent for his machine, dated 4 September 1917. Under the heading 'Improvements in Apparatus for use in connection with the Location of Submarines', the following details were given:

> According to this invention I attach to a float, preferably formed like a submarine, an apparatus consisting of a receptacle for material and means for cutting up and delivering the material into the water. The apparatus preferably consists of a square tube to receive the material having in it a pusher which intermittently expels the material from the tube, and a revolving knife which cuts the material as it issues from the tube. The pusher and knife are actuated either by means of a screw which revolves as the apparatus is drawn through the water or by means of a clockwork or electric motor. On the shaft of the screw or motor is a pinion in gear with a toothed wheel on another shaft upon which is mounted a revolving knife and another toothed wheel having a portion of its teeth omitted, the toothed wheel gearing with a nut on a screw on the stem of the pusher causing the pusher to move intermittently…The food is placed in the tube in layers separated by paper or other material so that it forms ribbons when cut and is in such a condition that when it is delivered into the water it floats upon the surface…The apparatus may be drawn beneath the surface of the water by means of a cable or may be attached to a buoy.[51]

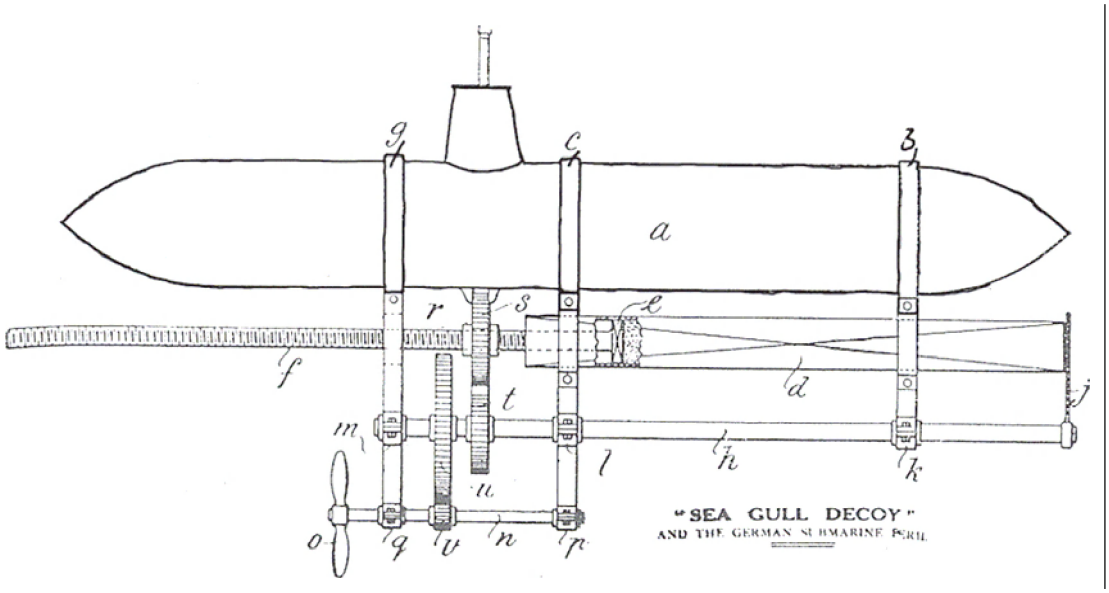

Fig 7. Thomas Mills's patented 'Sea Gull Decoy'. From 'The Fateful Sea-Gull', Reading: Bradley & Son, Ltd, 1919, p. 66. (The author has endeavoured to trace the copyright holder of this illustration. If he has unwittingly infringed copyright, please contact him.)

Mills was now on his own, and somewhat embittered by the failure of the authorities to realize that his method of submarine detection could save life and merchant tonnage, and win the war. He moved to Exmouth to carry out private trials with his 'No. 1' machine, and was given working space and the use of a launch, before he acquired his own, by the director of an east-coast steamship company, but in the search for bait encountered unco-operativeness from local butchers and fishermen, and had generally to rely on labour which he considered lethargic and expensive. He cooked the offal himself, and 'Many an evening I had to walk back to my hotel[52] dog-tired, and I did not seem to get any pity from anyone'. He also complained: 'Some of my daughters even said, "Father has a bee in his bonnet"'. Sea trials followed, with onlookers again suspected as spies.

A local report on Mills's activities which was not vetoed by the censor appeared in *The Exmouth Chronicle* on 8 December 1917, with further, illustrated reports on 16 February 1918 and in *The Exmouth Journal* on 23 February 1918. He told the *Journal*: 'I have found that by towing the dummy 200 or 300 yards behind the boat and making it show its periscope, it attracts birds. I then make it dive, and the gulls will follow it while it is under the water.' Mills recounted the experiences of whalers who used gulls to indicate the presence of whales, and he believed they could identify and be trained to follow submarines deep under water as well as at periscope depth.[53] Meanwhile, in August, the *Bystander* had published a cartoon by W. Heath Robinson, 'If Noah had been a German' (perhaps in this case Tirpitz), which Mills believed was an oblique reference if not to his own work then to the idea of using submarines to eject training bait, an idea which had been trivialized in the cartoon as a failed German experiment, thwarted by fish, in order to avoid censorship.[54] This idea had

also been mentioned by Commodore Hall,[55] and Mills reported that a naval friend told him it was 'what they had been doing'.[56]

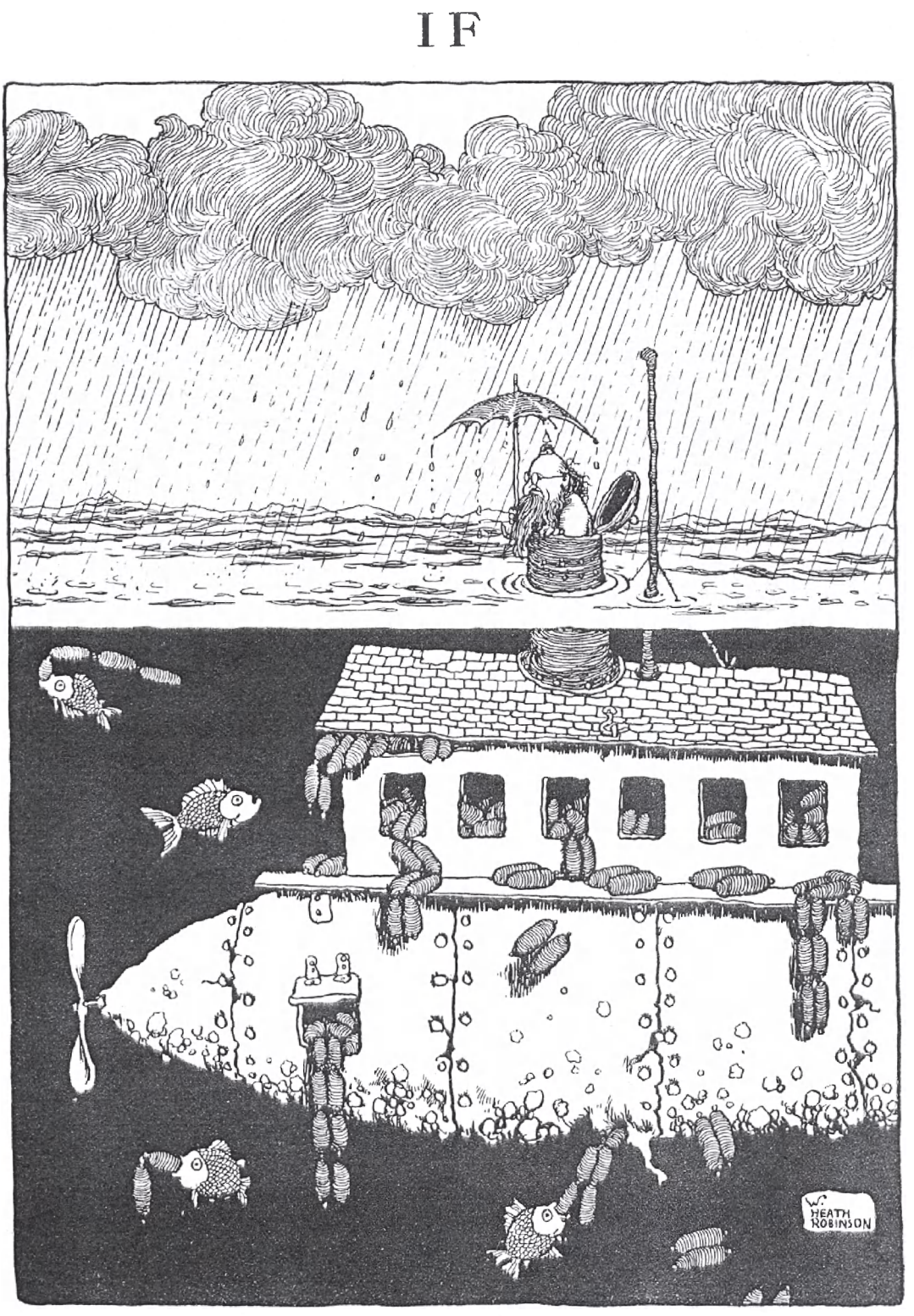

Fig 8. Cartoon from the 'Bystander', 29 August, 1917, by W Heath Robinson. Reproduced by courtesy of Pollinger Limited and the Estate of Mrs J C Robinson.

With his idea patented, and in the absence of support from the Admiralty, at the end of 1917 Mills decided he would send details of it, with photographs, to the national press and to political acquaintances including Members of Parliament and the Australian premier. He stated: 'I am fully prepared to hand to the Bank of England £5,000[57] in Government Security - the English or our Allies securities - that the submarine pest will practically be got rid of in six or eight months after the Admiralty have properly taken my proposals in hand.'[58] The limited response caused added frustration, and lack of newspaper coverage was blamed on the intervention of the Government Censor, as referred to in a letter from *The Aberdeen Free Press* of 14 January 1918. But mention of the possible training of seagulls to indicate the presence of enemy submarines had appeared in *The Pall Mall Gazette* on 7 January 1918.

Mills continued his trials until September 1918, in the meantime approaching once more (26 February 1918) and receiving a rebuff from the BIR (6 March 1918) when attempting to re-establish the credibility of his invention and secure for the Petrol Controllers its sanction for the purchase of petrol. Mills wrote with details of his method to Thomas Edison, but received a terse reply suggesting he should make a more formal approach to the Naval Consulting Board.[59] Although Mills stated that he did not do this because he was 'anxious that England should have the credit', the *San Francisco Chronicle* published on 10 March 1918 a sensational and imaginative front-page article on the effectiveness of the seagull method in undermining Admiral Tirpitz's strategy, reducing him to the condition of Coleridge's 'Ancient Mariner'. 'It is believed by the British Navy that the gulls, being carrion hunters, were first attracted to the U-boats by the frequent dead floating near them after the sinking of the steamers...They associate a U-boat with a feast…civilization has the sea-gull to thank.' Mills did not hesitate to assume that his work was the real basis of the story, and in his book this illustrated newspaper article is reproduced in modified form to incorporate the drawing of his patented device and a sea-trial photograph. He then finally decided to promote his idea within the American naval establishment, as when, on 16 May, he wrote to a friend with naval contacts who served on the Shipping Control Committee in New York.[60] Later, between September and December, he was in correspondence with the editors of *Popular Science Monthly* of New York, firstly to establish precedence over a Dr Pentz whom they had cited in an article concerning the seagull method, and then to forward his own photographs and patent details.[61]

Training gulls in August, using 'dummy submarine No. 4', Mills had by then won permission to use petrol for his launch, *Pride of the Harbour*, which he had previously converted to run on paraffin. Writing to the *Exmouth Chronicle* under the *nom de plume* of 'Super Tax Payer', he still hoped the authorities would try his method once more: 'I believe about eighteen months back they tried his plan and failed, through not following his instructions'; and, as before, he offered to underwrite the trials. In any case, he noted, 'If the Government did once get in a shipload of seals at an enormous price to catch the submarines, the English people did not laugh then, if the Germans did, for we are all liable to make mistakes'.[62] In September, Mills left Exmouth to return to his home in Sandhurst, Berkshire, believing that the role of the seagull in combating submarine piracy would remain essential for the future security of the civilized world.[63]

Fig 9. San Francisco Chronicle: front page feature of 10 March, 1918. Reproduced by courtesy of the San Francisco Chronicle.

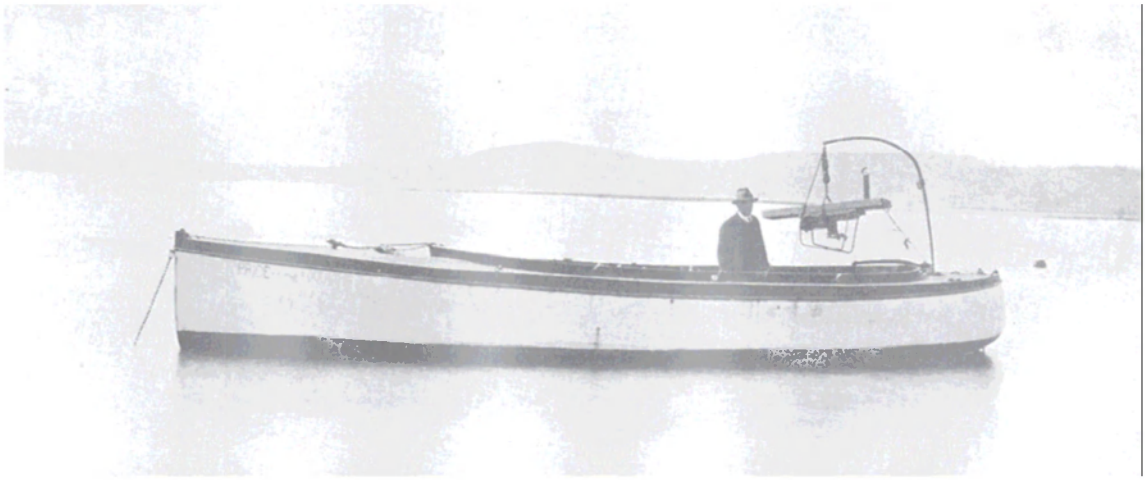

Fig 10. 'Pride of the Harbour', carrying patented device. From 'The Fateful Sea-Gull', Reading: Bradley & Son, Ltd, 1919, p. 68. (The author has endeavoured to trace the copyright holder of this illustration. If he has unwittingly infringed copyright, please contact him.)

Conclusion

Largely because of difficulties in its relations with the Royal Navy, the role of the BIR was declining in mid 1917. Its willingness to consider imaginative and surprising possibilities for anti-submarine measures, such as the seagull and sea lion proposals, made it increasingly vulnerable at a time when its credibility as an organization was under the closest scrutiny. These proposals represented a healthy inventiveness encouraged by crisis, but such acceptance of new ideas in a conservative naval environment was inevitably risky. With the vindication of convoys and then the development of ASDIC soon after the end of the war, these ideas, already declassified and in the public domain, were quickly forgotten as embarrassments.

The patriotic Thomas Mills, convinced of his method to the end, displayed some typical characteristics of the 'self-made man', being energetic, determined, self-reliant, thick-skinned and self-assured. He wrote in 1919: 'I fully believe the British Empire would have gone ahead if the Authorities had carried out my invention for the training of sea-gulls in a proper manner in February 1917.'[64] Frustration with the lack of interest in his work shown by these authorities made him bitter and critical, and his stubbornness soon gave way to obsession, so that his family appeared to have come to regard him as something of an uncompromising fanatic, judging by his own acknowledgement of their points of view. His decision to write the somewhat rambling and repetitive *The Fateful Sea-gull* no doubt gave him the opportunity to vent this frustration: 'I have had many hardships in my life, especially about fifty years ago in exploring and working, and even being stuck up by floods without food, but I never felt that as much as I have the rebuffs and insults experienced during the past two years, prior to the signing of the Armistice'.[65]

Although the first successful transatlantic convoy was realized in May 1917, Mills made no mention either of this or of the effectiveness of the earlier Scandinavian convoys; nor did he acknowledge that, as a result of the adoption of the convoy

system, the success of the U-boats declined in the second half of 1917. Instead, to emphasize the continuing need to apply his method, he cited the more pessimistic commentaries about the remaining U-boat menace, ironically echoing redundant German propaganda.

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[1] The proposals are mentioned in a few secondary sources and with varying degrees of accuracy: Hackmann, W.D. (1984) *Seek & Strike. Sonar, anti-submarine warfare and the Royal Navy 1914-54.* London: HMSO, pp. 19-20; Lubow, R.E. (1977) *The War Animals. The training and use of animals as weapons of war.* Garden City, New York: Doubleday & Co., Inc., pp. 31-2; Gusewelle, J.K. (1971) 'The Board of Invention and Research: a case study in the relations between academic science and the Royal Navy in Great Britain during the First World War.' University of California, Irvine: unpublished Ph.D. thesis, p. 41; and Kemp, P.K. (1952) *H.M. Submarines.* London: Herbert Jenkins, pp. 102-3.

[2] The sea lion trials, and the circumstances in which they were approved and managed, are discussed in D.A.H. Wilson, 'Sea lions, greasepaint and the U-boat threat: Admiralty scientists turn to the music hall in 1916'. *Notes and Records of the Royal Society of London*, lv (2001), 425-455 (accessible online), and 'Admiralty science, U-boats and the performing arts, 1916-1917'. *Journal of Defence Science*, vol. 6 (2), 157-167.

[3] The help of other psychologists was enlisted after the formation by a group of businessmen of the Lancashire Anti-Submarine Committee in 1917, under the chairmanship of Sir Ernest Rutherford. Staff of the Cambridge Psychological Laboratory participated in the selection and training of personnel for

hydrophone work. (Among the Cambridge staff was Miss E.M. Smith, the animal psychologist, but she was not invited to become involved in the work with sea-lions or birds described below.) Bartlett, F.C. (1937) Cambridge, England 1887-1937. *American Journal of Psychology*, 50: 97-110.

[4] See, for example, J.H. Capshew (1993) 'Engineering behavior: Project Pigeon, World War II, and the conditioning of B.F. Skinner'. *Technology and Culture*, 34 (4), 835-857; M.E. Conboy (1975) 'Project "quick find": a marine mammal system for object recovery'. *Rapp. P.-v. Reun. Cons. Int. Explor. Mer.*, vol. 169, 487-500; and V. Murphy (2003) 'Let slip the sea lions of war'. http://news.bbc.co.uk/1/hi/world/middle_east/2839155.stm.

[5] Newbolt, H. (1928) *History of the Great War based on official documents by direction of the Historical Section of the Committee of Imperial Defence. Naval Operations. Vol. IV*. London: Longmans, Green and Co., p. 323.

[6] Admiral of the Fleet, The Rt Hon. The Earl Jellicoe (1934) *The submarine peril. The Admiralty policy in 1917*. London: Cassell, p. 5.

[7] Newbolt (1928) op. cit., p. 324.

[8] Newbolt (1928) op. cit., pp. 323-4.

[9] Newbolt (1928) op. cit., pp. 27 & 323.

[10] Unrestricted Submarine Warfare meant the 'sinking of merchant-ships by torpedoes at sight and without warning'. Jellicoe in Foreword, p.viii, to Gibson, R.H. and Prendergast, M. (1931) *The German submarine war 1914-1918*. London: Constable and Co. Ltd.

[11] Fayle, C.E. (1920-4) *History of the Great War. Seaborne trade.* Vol. II. London: John Murray.

[12] Marder, A.J. (1969) *From the Dreadnought to Scapa Flow. The Royal Navy in the Fisher era, 1904-1919. Volume IV 1917: year of crisis*. London: Oxford University Press, p. 51.

[13] Admiral of the Fleet Viscount Jellicoe of Scapa (1920) *The crisis of the naval war*. London: Cassell & Co. Ltd, p. 4.

[14] Newbolt (1928) op. cit., p. 385.

[15] Jellicoe (1920) op. cit., pp. 33, 37 & 181; (1934) op. cit.

[16] Since December 1916, this method of 'protected sailings' had been limited to the Scandinavian trade, using trawlers and because of the insistence of the Scandinavian ship owners. E. Keble Chatterton (1923) *The Auxiliary Patrol*. London: Sidgwick and Jackson Ltd, pp. 216-17.

[17] Sims, W.S. (1920) In collaboration with Burton J. Hendrick. *The victory at sea.* London: John Murray, p. 96.

[18] D.R. Messimer (2001) *Find and destroy: antisubmarine warfare in World War I*. Annapolis, Maryland: Naval Institute Press, p. 155.

[19] This was one of six Sections, and included in its area of responsibility the detection of submarines and mines. Its secretary was Sir Richard Paget, Bt, who later developed what came to be known as the Paget Gorman method of signed speech.

[20] Jellicoe (1920) op. cit., p. 4 and (1934) op. cit., p. 5.

[21] Caroe, G.M. (1978) *William Henry Bragg 1862-1942. Man and scientist*. Cambridge: Cambridge University Press, p. 88.

[22] MacLeod, R.M. and Andrews, K.A. (1971) Scientific advice in the war at sea, 1915-1917: the Board of Invention and Research. *Journal of Contemporary History* Vol. 6, no.2, pp. 3-40. This article is as much an account of naval hostility to the intrusion of civilian scientists as one about the achievements of the BIR, and the difficult environment is also thoroughly discussed in Hackmann (op. cit.).

[23] Jellicoe (1920) op. cit., p. 54.

[24] Sims (1920) op. cit., p. 23.

[25] Newbolt, H. (1931) *History of the Great War based on official documents by direction of the Historical Section of the Committee of Imperial Defence. Naval Operations. Vol. V* London: Longmans, Green and Co., pp. 23, 58-9 & 138. It could also be argued that publication of accurate information might have reinforced enemy policy. The Chief Naval Censor believed it necessary also to deny the enemy means of checking their submarine officers' reports and deciding which trades or areas to concentrate on. Brownrigg, D. (1920) *Indiscretions of the Naval Censor.* London: Cassell and Co. Ltd, p. 127. When later the effectiveness of their U-boats declined, the German authorities attempted to maintain public confidence by themselves falsifying levels of British, allied and neutral merchant tonnage losses.

[26] Conversely, U-boat successes, and the ineffectiveness of British measures against them, were of course played upon in the German press. See, for example, the leading article in the *Kölnische Zeitung* of 1 August 1917 by Kapt. von Kühlwetter, chief press agent of the German admiralty.

[27] Newbolt (1928) op. cit., p. 70.

[28] Simpson, C. (1972; 1983) *Lusitania*. London: Longman; Harmondsworth: Penguin Books Ltd, pp. 37-8. The present author has not been able to establish from family or archival sources any evidence of Inglefield's interest in such use of gulls.

[29] MacLeod and Andrews (1971) op. cit., p. 6.

[30] Hackmann (1984) op. cit., pp. xxiv, 13, 14 & 18. Marder notes that 20,698 of these suggestions were submitted to the BIR between July 1915 and December 1916. Marder, A.J. (1959) *Fear God and Dread Nought. Vol. III: Restoration, abdication and last years 1914-1920.* London: Jonathan Cape, p. 270 (original source: Public Record Office [hereafter PRO] ADM 212/158). The Holland-Skinner Report stated that the number of inventions dealt with by Section II between 5 July 1915 and 30 June 1917 was 14,655, of which 9,825 concerned appliances to destroy submarines, the highest figure for any subject of any section. The overall total of inventions submitted to every section in this period was 41,127. (PRO ADM 212/158.)

[31] *Grand Fleet Secret Packs 1914-18*, vol. XLVII, Pack 0022, Sections C, D1, D2, PRO ADM 137/1927; vol. XLVIII, Pack 0022, Section D3, PRO ADM 137/1928.

[32] Naval Staff, Admiralty (1920) *The technical history of the Navy.* TH 40, p. 63.

[33] Jellicoe (1934) op. cit., p. 36; Kemp, P.K. (1952) op. cit., p. 103; Marder (1969) op. cit., p. 79; and 'Blackening the moon'. *Evening News*, 26 February 1919.

[34] Brief reference is made to Mills in R. Compton-Hall (1991) *Submarines and the war at sea 1914-18.* London: Macmillan, pp. 94-5.

[35]Memorandum of the Meeting of the Sub Committee of Section II, held on Tuesday April 24th 1917, PRO ADM 293/5, p. 391. Parsons referred to the similar manner in which gamekeepers locate vermin by observing the movement of birds.

[36] He complained in 1928: 'One hears no mention of Downing Street follies, such as Sea-Lions on which we were forced to waste time and energy'; and in 1931: 'Valuable time, personnel, and money had in fact to be wasted to prove the futility and childishness of this contention'. Quoted in: A.J. Marder (1969) op. cit., pp. 78 & 162, citing a draft of a letter from Duff to Jellicoe, August 1928. In a

highly classified report to the First Lord on 5 February 1917 concerning all ongoing anti-submarine measures, Duff had much earlier described as 'extraordinary' the BIR's attempts to 'chase submarines with packs of seals ... on a Scotch Loch'. PRO ADM 137/1927.

[37] Mills later claimed he had seen them hundreds of miles from the Australian coast. Another problem was how to ensure that the behaviour of trained birds would be imitated by others and permeate the gull population (Kemp, 1952, op. cit.), but Mills had reported that each year at Exmouth he would start training a new generation, the parents having migrated.

[38]PRO ADM 293/7.

[39]PRO ADM 293/5, p. 413; BIR Memorandum of Meeting of Sub-Committee, Section II, held on Wednesday May 23rd 1917. BIR Reports etc. 1915-1917 (Admiralty Library).

[40] Kemp (1952, op. cit.) believed that preliminary trials were carried out in the Solent.

[41]Hudson (1841-1922) is assessed in Allen, D.E. (1994) *The naturalist in Britain: a social history*. 2nd ed. New Jersey: Princeton University Press, pp. 206-7 & 210. By 1917, Hudson was ill, and also caring for his ill wife. He left no record of this episode, having ordered his executors to destroy his papers and to discountenance any biography.

[42]PRO ADM 293/5, p. 424.

[43] BIR Memorandum of Preliminary Meeting of Sub-Committee, Section II, held on Tuesday July 17th 1917. BIR Reports etc. 1915-1917 (Admiralty Library, London).

[44]PRO ADM 293/5, p. 444. Lubow described this as 'a truly novel approach … exquisitely simple', and said rather vaguely that it was reported that British submarines submerged off the English coast released large amounts of bread which floated to the surface and attracted flocks of seagulls. 'No information is available as to how many times this association of events, behavior and submarine, had to be repeated before the seagulls began to appear at the sight of the submarine alone. However, it is told that when the gulls spotted a long, dark shadow moving beneath the surface of the waters, they would proceed to flock to that place ... observed by human spotters on the shore.' If the reported location did not coincide with the known position of a friendly submarine, countermeasures would be taken. 'It is not known how many German U-boats became victims of the scavenger gull's insatiable search for food.' Lubow (1977) op. cit.

[45]PRO ADM 293/7. A brief account of the eccentric Kearton brothers, who promoted wild bird photography and developed strange but effective camouflage and hides for bird watchers, can be found in D.E. Allen (1994) ibid., p. 211. See also Mitchell, W.R. (2001) *Watch the birdie*. Giggleswick: Castleberg, p. 99. Richard Kearton's daughter made very brief mention of his involvement in this unsuccessful trial, but no other reference to it has been found either in his publications or in Kearton papers collected by Mitchell and donated to the University of Bradford (part of the W.R. Mitchell Archive).

[46] BIR scientists had first arrived at Hawkcraig in November 1915, and one of them, Albert Wood, later wrote to Sir Ernest Rutherford of Section II: 'Commander Ryan…said that it [B3] was to be used by both of us [Navy and BIR]. He could not tell us, however, when we could have it for our own use; indicating that it would be possible for us to have it only on those occasions when he did not require it himself - which occasions from our previous experience will probably be rare'. Fisher Papers, St Andrews University Library, 1192, Wood to Rutherford, 22 March 1916, cited by MacLeod and Andrews (1971) op. cit., p. 21.

[47] Hackmann (1984) op. cit., p. 29. An example of the attitude of the Royal Navy is a comment made by Commodore Hall about the level of co-operation thought necessary: 'The only information to be given [by naval officers to BIR scientists] was that the enemy submarines were in the sea and that means were required to detect their presence'. Memorandum of the Meeting of the Sub Committee of Section II, held on Tuesday March 27th 1917, and quoted in 'Report on the Present Organization of the BIR' (also known as the Holland-Skinner Report), September 1917, p. 7. PRO ADM 116/1430, as

cited by MacLeod and Andrews (1971, op. cit., p. 28). The report reveals the failure of the Royal Navy to recognize the validity and contributions of civilian science.

[48] *Grand Fleet Secret Packs 1914-1918*, vol. XLVII, Pack 0022, Section D2, pp. 360-8. PRO ADM 137/1927.

[49] Mills, T. (1919) *The Fateful Sea-Gull*. Reading: Bradley & Son, Ltd, p. 57. *The Fateful Sea-Gull* consists mainly of Mills's account of his successful background and patriotism, a full and often repetitive description of the development and testing of his seagull method, and selected reprints of parliamentary and press reports that highlight both the seriousness of the U-boat problem and the shortcomings of Admiralty policy in organization, research and experiment. (The date of publication given is that recorded in the British Library catalogue. However, references in the book to occurrences in December 1919 suggest that it was actually published later. A date of publication does not appear in the volume itself.)

[50] This problem might result in misdirected countermeasures. One of Mills's sons later wrote in March 1918 to report a conversation with someone who had apparently served on the BIR, and who referred to another possible consequence of the problem: 'We have got submarines blockading the German coast, therefore it would be a grand thing for the Huns if the sea-gulls were to hover over them; they could send out an aeroplane and soon finish them all off…' Mills (1919) op. cit., p. 76.

[51] Mills (1919) op. cit., p. 64.

[52] The Imperial Hotel, Exmouth, where he stayed for a year.

[53] Talbot claimed that lookouts on patrolling vessels took careful note of the behaviour of sea birds, which would follow a submerged submarine relentlessly and expectantly. Talbot, F.A. (1915) *Submarines: their mechanism and operation*. London: Heinemann, p. 236. During the BIR's sea lion experiments at Lake Bala between March and July, 1917, curious gulls that circled above the sea lion as it surfaced for air for less than a second (after remaining submerged for up to a minute at a time) had sometimes helped as intermediate observers: 'We were often greatly helped in following the track of the animals, and in finding them when they were lost by watching the action of the gulls. These birds were always disturbed when one of the sea-lions came near them, and they often followed the animals for considerable distances, circling round above them, and swooping down when the sea-lion put his head out of the water to breathe'. E.J. Allen, *Report upon experiments on the hearing powers of sea-lions under water, and on the possibility of training these animals as submarine trackers*, BIR 30051/17 (Admiralty Board of Invention and Research, London, 1917), p. 10, full document preserved as PRO ADM 293/5, pp. 450-469; and Wilson (2001) op. cit., p. 443.

[54] The *Bystander*, 29 August 1917, p. 403.

[55] Memorandum of the Meeting of the Sub Committee of Section II, held on Tuesday April 24th 1917, PRO ADM 293/5, p. 391.

[56] Mills (1919) op. cit., p. 69. The friend may have been Captain L.C. Cock, who had helped arrange Mills's meeting with Admiral Sir James Starten and who later wrote letters of encouragement to Mills.

[57] Mills believed about 1,000 decoys at £5 each would be needed for trawlers and patrol boats.

[58] Mills (1919) op. cit., p. 75.

[59] Mills's letter of 16 February, 1918 from the Imperial Hotel, Exmouth was addressed to Edison at his laboratory in Orange, N.J., saying: 'I send you a few photographs and a cutting from a newspaper. By this, no doubt, you will see that I am trying to train sea-gulls to follow submarines, under the water as well as on the surface. I am looking forward to your new invention, and I hope you will be successful, and that you are in good health. I have kept this matter to myself so if I do not hear from you I shall not be offended.' On 11 March he received a reply from 'W.H.M.': 'Your recent favour has been received. We beg to say that Mr Edison is working night and day for the Government and cannot possibly spare the time to personally examine suggestions or inventions offered in connection with matters of

National Defence. He has, therefore, directed that communications of this kind be returned to the writers, with the suggestion that they communicate direct with Mr Thomas Robbins, secretary of the Naval Consulting Board, 13 Park Row, New York, N.Y. Mr Edison has been away from home for several months, and we do not know when he will return. Therefore, he has not seen your communication, and we return it herewith.' Mills (1919) op. cit., pp. 110-11. The author is grateful to the editor of *IJNH* for pointing out that Edison chaired the Naval Consulting Board and worked with the National Research Council (founded by Congress as an arm of the National Academy of Sciences just as the United States entered the First World War), one of whose tasks, like that of the BIR, was to review innovation of every sort, both well-conceived and hairbrained. It would appear that Mills had aspired to have his imaginative and enterprising work recognized by Edison at a more personal level. Like the BIR, the NRC included prominent academic scientists as well as those from an industrial background. Their role of screening the huge number of suggestions from lay sources could not be handled on the personal basis Mills hoped for; and it could also be that as a self-assured amateur inventor he mistakenly hoped to be accepted on equal terms by an eminent applied scientist in the person of Edison himself.

[60] Mills (1919) op. cit., p. 122.

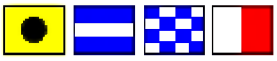
[61] Mills (1919) op. cit., p. 153.

[62] Letter to the *Exmouth Chronicle*, 24 August 1918. It is reproduced in his book (p. 144), alongside one of the six photographs from 'Sea-lions that hunted U-boats' in the *Illustrated London News* of 5 April 1919, pp. 480-481.

[63] Mills (1919) op. cit., p. 210.

[64] Mills (1919) op. cit., p. 160.

[65] Mills (1919) op. cit., p. 66.



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