Ocean Sentinels

Seabirds and the lively governance of marine ecologies

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Abstract

The ocean is increasingly central to discussions about planetary futures. Its unruly effects on the global climate system and its ecological unravelling at the hands of decades of intense exploitation feed narratives of crisis, whilst redemption is proposed in new blueprints for sustainable development aligned with enlightened marine stewardship. This thesis is concerned with the changing more-than-human collectives, technologies, and practices implicated in knowing and governing the Anthropocene ocean. My specific focus is on seabirds, which are one of the most globally threatened bird groups and are used as key indicators, or sentinels, of marine environmental change. As sentinels, seabirds are put to work to know and govern ocean spaces and ecologies in diverse ways, and they illuminate a wider set of knowledge and environmental governance practices operating through animal bodies. I begin my exploration of these practices by tracing the emergence and shifting character of seabird sentinels from the 1950s to the present. My focus then turns to two distinct, digitally-mediated ways in which a particular group of seabirds – albatrosses – are operationalised as sentinels to govern ocean space. Lastly, I consider the limitations of digital transformations in environmental monitoring, specifically those meant to render the incidental catch of seabirds in fisheries visible to decision-makers. Through these cases, the thesis develops sentinel geographies as a novel field of geographical enquiry which accounts for these varied practices, the lively agencies of the nonhumans entangled with them, and the broader political economic relations within which they unfold. The practical implications of this research concern the needs for situated ethical frameworks regarding sentinel animals' use in environmental knowledge production and governance, for questioning the naturalisation of surveillance as a marine governance technique, and for critically appraising data-driven transparency as a governance ideal in light of how it manifests in practice. In conclusion, I further articulate the promise of sentinel geographies for future geographical research on the digital mediation of human-nonhuman relations and the roles of animals in environmental sensing and governance.

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Chapter One

Introduction

1.1. On the cliffs at Bempton

A forbidding thicket of scrub stands between the RSPB parking lot at Bempton, East Yorkshire, and the coastal cliffs that bring visitors, human and bird alike, to this site. Little in this landscape of hedges, fields, and roads suggests the nearby presence of the sea. A wooden sign points me down a narrow path weaving through the bushes, and, once through, I emerge into a meadow. A barn owl dips low over the field in the evening light and the long, early summer grasses that conceal its rodent prey struggle in the stiff breeze. The scrub hasn't just been sheltering me from the wind, it turns out, but also the smell; acrid, oceanic, and not-quite-organic. As I approach the cliffs, the smell and sounds intensify until eventually the seabirds come into sight. Thousands of them, bringing back tales and food from the North Sea. Gannets gather in groups near the top of the cliff, where there is more space to land. Fulmars and smaller birds, hard to identify from a distance, ferry busily to and from the steep cliffside below, landing on impossibly narrow ledges packed with other birds. Still further below, rafts of gulls and guillemots bob placidly on the sea beyond the breaking waves.

The cliffs of Bempton, Flamborough, and Filey along the East Yorkshire coast support the largest mainland seabird colony in England. Around half a million birds congregate annually around these white chalk faces, journeying from across the North Sea to breed here in the early summer. Amidst this vast gathering, one individual bird has caused a great stir amongst amateur birdwatchers and has drawn me, too, to visit the cliffs. A black-browed albatross has been sighted occasionally at various sites around the North Sea, from Yorkshire to Germany and Denmark, in the previous few years. Affectionately nicknamed 'Albert Ross' or 'Albie,' the provenance of this albatross – thought to be the only individual of its species in the Northern Hemisphere - is uncertain. Likely it was blown off course by a storm from the South Atlantic in 2014, like another black-browed albatross (also known as Albert Ross) that was first spotted in the Firth of Forth in 1967 and subsequently around Scotland until the mid-2000s. After some nervous online speculation that this bird might have perished in the talons of a Danish sea eagle, a flurry of excited social media posts tell me that it has come to Bempton. I spend two days standing atop the cliffs, sometimes watching, sometimes conversing with other birdwatchers who have come to see this out-of-place charismatic

seabird. Some have taken time off work and woken up at unpalatable times to drive across the country to be here. An encounter with the albatross eludes us, but as we talk to pass the time, the bird becomes a way into discussions whose themes, as much as albatrosses and other seabirds themselves, are central to this research. Foremost amongst these, I am frequently told that Bempton is, nowadays, an atypical seabird colony. Populations of many of the species breeding here are relatively stable, even growing, owing to the improving ecological health of parts of the North Sea and nearby availability of their fish prey (Clarkson et al. 2022). By contrast, many once-bustling avian communities like this one have reduced greatly in their liveliness, some even falling silent entirely. A general trend in seabird populations globally is one of concerning decline over the past several decades (Dias et al. 2019).

1.2. Seabirds in decline

Together, seabirds are amongst the most threatened groups of birds worldwide. Faced with pressures in the marine environment – from commercial fishing, in terms of competition for food resources and bycatch, as well as pollution and climate-induced ecosystem change – and on land – from predation by invasive species, human disturbance, and habitat degradation – their conservation status has deteriorated rapidly over recent decades (Croxall et al. 2012a; Dias et al. 2019). There are many reasons to be concerned about this. Conservationists might point towards biodiversity loss or, more recently, loss of ecosystem services as important concerns. Socially and culturally, these declines are also significant, eroding diverse more and less convivial human-seabird relations that have formed over centuries in different places (Barwell 2013; Nicolson 2017). For environmental humanities scholar Thom van Dooren, these declines also signal the breaking down of seabirds' unique ways of life, or 'flight ways,' which are "shared, produced and nurtured in the world through the work of successive generations of living beings" (Van Dooren 2014, 22). This breakdown, we can imagine, is felt meaningfully by the birds themselves.

Understanding these flight ways as entangled within expansive webs of ecological relations, the implications become more concerning still. Indeed, ecologists suggest that

seabirds “ring the alarm” on planetary marine ecological decline (Næss 2021; see also Sydeman et al. 2021; Velarde et al. 2019). Approached through observations of seabirds, the ocean comes into view as an increasingly turbulent, contaminated, and biologically depleted space. As not only one of the most threatened but also most studied groups of marine organisms, such is the view of the ocean that seabirds provide that scientists have recently used them to trace global patterns in the effects of climate change and human activities on ocean ecosystems (Sydeman et al. 2021). Some even suggest that seabirds might act as guides for rethinking how to coordinate human actions in and for an ocean in crisis (Lescroël et al. 2016). Birds more generally have been identified as important indicators of ecosystem health and change. Recent scientific accounts draw associations between bird populations in steep decline and profound planetary anthropogenic environmental change (BirdLife International 2018; Lees et al. 2022), suggesting birds afford “unparalleled insight into the health of the natural world as a whole” (BirdLife International 2022, 14). Monitoring their populations is positioned as a viable proxy for monitoring ecosystem transformations in the Anthropocene. Their longstanding popularity – as subjects of amateur observation, literary and artistic representations, and pet-keeping, for instance (see Petri and Guida 2023) – moreover foregrounds birds as important vehicles by which to communicate environmental changes through affective registers.

1.3. Environmental sentinels

In contemporary Western scientific parlance, it has become commonplace to refer to birds’ roles as *environmental sentinels.* Sentinel is a term initially appropriated from military settings, where it refers to a soldier who advances ahead of others or remains otherwise vigilant for an approaching threat. In its ongoing use in military and surveillance contexts the term’s contemporary applications are varied, from drones to counter-terrorism operations and the European Space Agency’s Earth observing satellites, where an emphasis on vigilance and early warning is shared. In the biological sciences, sentinels denote a diversity of nonhumans which draw attention to particular environmental phenomena before they might otherwise be registered and give warning of their implications. For instance, well-known in relation to Rachel Carson’s ‘Silent Spring’ (1962), decisions to ban the use of organochlorine

pesticides and industrial chemicals like DDT and PCBs were made on the basis of evidence of their effects on wildlife, notably predatory birds, before their human health effects were understood (Committee on Animals as Monitors of Environmental Hazards 1991). Corals and polar bears are some of the better-known examples of nonhumans that have recently been used to signal and draw attention to the effects of climate change on ocean and Arctic ecosystems (Benson 2013; Hughes et al. 2017). In such examples, bodily sensitivity to environmental changes, often as well as particular charismatic affordances, distinguish particular animals as suitable sentinels over others.

Although the character of such practices is new, the bodies and sensory capacities of animals – especially birds – have long afforded ways of attuning to environmental processes and unfolding events beyond human perception. As ethno-ornithologist Nicole Sault (2010, 292) observes, birds across varied contexts have been "important for the messages they send out […] they are beings with knowledge that can benefit people in everyday life, as well as in critical times of change and disaster." Migrating birds have been used to forecast seasonal changes and weather events; canaries carried into mines to detect noxious gases; and seabirds used by fishers as sensory extensions alerting them to the location of fish (Furness et al. 1993; MacDonald et al. 1997; Wakefield and Braun 2019). The ancient Roman practice of augury, and its Greek equivalent ornithomancy, entailed reading omens and interpreting divine intention by studying the behaviours of birds (Shemesh 2018). The interpretations gleaned from these observations informed diverse human activities from military operations to weather forecasting and journey planning (Mynott 2018). In a very different context, the Norwegian proverb 'fuglan veit' ('only the birds know') points to a longstanding recognition of birds as lively, material mediators between humans and the unknown.[1]

In scientific practices, there is also historical precedent to the contemporary use of nonhumans as environmental sentinels. For instance, in nineteenth-century Paris, Finnish lichenologist Wilhelm Nylander observed the relations between certain lichens and air pollution in the city, suggesting that lichens could be used as a 'hygiometer' of the environment (see Vitikainen 2001). Fish were commonly used in early-twentieth century

[1] See https://uit.no/project/fuglan (last accessed: 01.06.23)

Germany to study river pollution, and the widespread practice of using bivalves like mussels to monitor aquatic ecosystem health has been in use since the 1970s (Goldberg 1975; Lakoff 2016). A widely cited first study approaching seabirds in this way dates from 1978 (Dee Boersma 1978). What differentiates newer applications of environmental sentinels from these practices is the diversity of contexts in which they are now used, their entanglement with a range of digital sensing technologies and infrastructures, and their orientation towards signalling not only localised environmental changes, but those occurring at the level of whole ecosystems or the planet (see Jetz et al. 2022). For instance, 'biologging' – the collection of movement, behavioural, and environmental data using animal-borne digital devices – has become an integral feature of wildlife research (Kays et al. 2015; Hussey et al. 2015; Wilmers et al. 2015). However, beyond an early focus on using these techniques to understand animals' lifeworlds, ecologists – such as those operating under the International Cooperation for Animal Research Using Space (ICARUS) initiative – are now developing global networks of instrumented animals across multiple taxa for 'biological Earth observation' (Jetz et al. 2022). These, in turn, are informing novel modes of responsive, real-time environmental management (Hobday and Hartog 2014; Maxwell et al. 2015).

Scholars across geography, anthropology, and science and technology studies have recently developed an interest in these environmental sentinels. Research on this topic has explored how, through varied practices from modelling to everyday acts of noticing in local communities, nonhuman beings facilitate sensing, predicting, and responding to socioecological changes (Gramaglia and Sampaio da Silva 2012; Johnson 2017; Kosek 2010; Keck and Lakoff 2013; Paredes 2022). These studies form part of a wider project interrogating the distribution of environmental sensing practices across more-than-human assemblages (see Gabrys 2016a; 2019b; Lenton and Latour 2018; H. Pritchard 2013). The environmental information produced by and with animal sentinels might be seen, by way of this work, as increasingly inseparable from a much broader "more-than-human sensorium for the Anthropocene" (Johnson 2017, 278) which enables novel ways of governing unruly environmental conditions and circulations (see Chandler 2018; Lockhart et al. 2023). This has variously been described as a 'Gaia 2.0' (Lenton and Latour 2018) or 'Gaia's Web' (Bakker 2024) whereby environmental management enabled by new sensing technologies becomes part of the operation of the Earth system.

The ocean has figured particularly prominently in these literatures on environmental sensing and, indeed, is a space where the intrusion of various sensing technologies has been especially acute. This attests to the difficulty of sensing ocean spaces through direct, embodied human presence, such that knowledge of the ocean has come to rely upon distributed networks of sensing technologies, transforming marine domains into "highly instrumented sensor spaces" (Gabrys 2016b, 140; see also Lehman 2018). It also speaks to a growing sense that knowing the ocean is central to imagining and practicing planetary futures and politics, whether expressed through prevalent diagnoses of an 'ocean in crisis,' emerging 'Blue Economy' discourses linking human futures with 'sustainable use' of ocean resources, or mounting uncertainty about the abilities of present scientific models to capture ocean dynamics and their powerful future effects on the climate (Su et al. 2023). Ocean sensing practices, in these contexts, are not just targeted towards new understandings of physical ocean processes and ecological dynamics, but also novel forms of governance (see Bakker 2022).

Through these technologies, ocean sensing and governance become performed by what Louise Amoore and Rita Raley (2017, 7) term a "composite figure of distributed human and nonhuman agency."[2] However, the conceptualisation of the nonhuman in existing accounts remains distinctly technological. The vital roles played by animals, often entangled with technological forms of agency, in how humans come to act in and for the oceans has received less attention from geographers and scholars in related disciplines. Where this has been discussed, animals have been described as sensors (Gabrys 2016a; Benson 2011) and as oceanographers (Forssman 2017); I suggest different understandings emerge when we come to see them additionally, following scientists' own framings, as sentinels. As I outline in Chapter Two, this distinction does not imply a binary between sensors and sentinels, but rather draws out how particular nonhumans' sensing practices and embededness in human sensing infrastructures are configured into messages or warnings of environmental change intended to incite political action.

[2] Amoore and Raley make this observation not in the context of ocean sensing but of security apparatuses operating through algorithms. Their point, however, is applicable here too and has been made by others (e.g. Johnson 2020).

By way of an empirical account of the histories and contemporary practices and politics of sensing (with) seabirds, this research develops a novel theorisation of environmental sentinels. Specifically, I put forward 'sentinel geographies' as a novel field of geographical inquiry which attends to environmental sentinels as devices, collectives, and practices. I do so in order to offer new insights into the more-than-human technologies, collectives, and practices implicated in knowing and governing the Anthropocene's turbulent ecologies. By moving from existing and diverse engagements with sentinel species towards the notion of sentinel geographies, the thesis proposes a way to engage with sentinels as more than the individual animals or species studied for early warnings of environmental change, as also the characteristic of the more-than-human systems assembled to derive such warnings, make visible the interconnectedness between environmental and human systems, and to guide environmental governance accordingly. This builds upon recent interest in 'sentinel territories' as "spaces where early-warning signals of environmental threats can be observed" (Blanchon et al. 2020, 1), viewing such territories as one spatial component of broader sentinel geographies configured around organismal signalling, which involve interacting human and nonhuman beings and modes of experience and observation, technologies, physical phenomena, and specific governance interventions and practices. A conceptual framework for sentinel geographies is developed in Chapter Two which bridges across literatures in more-than-human geography, geographies and histories of science, science and technology studies, and the emerging field of digital environmental geography. The framework builds on these through a set of conceptual developments, which are worked through across the four empirical chapters of the thesis. Each of these captures different dimensions of how seabirds operate as sentinels and with what implications. The research questions that each of these chapters addresses are outlined in section 1.5, while the chapters themselves are detailed further in the thesis roadmap offered in section 1.6. For now, I turn to elaborate on the selection of seabirds – and, in particular, albatrosses – as the focus for this research and further specify the situations which this thesis explores.

1.4. Seabirds as ocean sentinels

This thesis suggests that, in their diversity, environmental sentinels offer geographers new opportunities to engage emerging ways of knowing and governing the Anthropocene. By bridging across existing work and bringing it into conversation with literatures that have thus far had little to say about sentinels, my intention is to highlight some of these opportunities. I do so through a particular 'type' of environmental sentinel – seabirds – and with attention to a specific environment – the ocean. My proposition, which derives from extensive reading and conversations with a wider cast of 'sentinel scientists,'[3] is that this focus allows for the development of concepts and approaches that will be helpful to researchers studying other sentinels in other contexts. However, I approach broad generalisations with caution – they tend to obscure as much as they reveal - and, indeed, the specificity of *this* context interests me as much as how it might be made to travel further. In Chapter Two, I detail why the ocean is appealing as a focus for scholars interested in transformations in environmental sensing and governance practices, attending particularly to the entanglement of knowledge production, technologies, and geopolitics in ocean governance. Here, I further specify the selection of seabirds as an appropriate focus for this study and provide an overview of a specific conservation problem which gives a common focus to my empirical chapters – seabird bycatch in commercial fisheries.

1.4.1. Seabird affordances

Scholars interested in the scientific practices of using animals as environmental sentinels have shown how these rely fundamentally upon the affordances of the individual beings and species under study. Geographer Jamie Lorimer (2007, 914) describes affordances as "the inherent, ecological characteristics of a nonhuman in relation to the phenomenological apparatus of the body (human or nonhuman) that encounters and perceives them." It is these ecological characteristics and the ways in which they are perceived by human and technological apparatuses which allow nonhumans to act as sentinels; to 'speak' for environments and make the problems affecting them known to humans (see Gramaglia and Sampaio da Silva 2012). In listening for these messages from the nonhuman world, sociologist Jennifer Gabrys (2018, 354) suggests that humans might become attuned to

[3] This is my term, rather than one frequently used by scientists to describe themselves. However, it is evidenced by researchers and entire research centres dedicated to the study of sentinel species. See, for example, https://ecosystemsentinels.org/the-center-for-ecosystem-sentinels/ (last accessed 03.02.23)

"multiple modalities for 'taking measure' of environments." What, then, makes seabirds' modalities for taking measure of environments particularly interesting to scientists and practitioners, and what affordances do these rely upon?

There are, undoubtedly, too many to review comprehensively. From the herring and black-bucked gulls familiar to urban residents for their proclivities for rubbish and take-away meals, to burrow-nesting storm petrels scarcely larger than a swallow, seabirds are an extremely diverse bunch. Nearly 350 bird species are classified as seabirds, depending on the marine environment for part of their life cycle.[4] Nevertheless, some key commonalities in seabirds' 'flight ways' (Van Dooren 2014) can be distilled. Seabirds are beings of a world we usually divide into distinct spaces – the coastal shore and the volumetric spaces above and below the surface of the ocean. Many of the characteristics they share, such as long lifespans, broad distributions, low reproductive rates, and high adult survival rates reflect millennia of correspondences with this world. In the cost-benefit language of biologists, these are adaptations to the patchy distributions of their prey species at sea, and reflect the significant costs of locating and bringing this food back to their partners and offspring on shore (e.g. Ricklefs 1990; Weimerskirch 2007).

As wide-ranging marine predators, seabirds cover large areas of ocean in search of prey. Some use a technique known as 'dynamic soaring' to receive most of the energy needed for their flight from the wind and its interplay with the ocean surface (Figure 1). In high winds, some species can fly in this way at speeds exceeding 100km per hour. Repurposing philosopher Peter Sloterdijk's (2011, 44) observations of the "pneumatic pact" coupling the breather and the breathed upon, we might observe that the birds and the wind – animal and environment – "are bonded by an intimate complicity."

[4] See lists at the following links: https://www.fisheryandseabird.info/documentation/list-determination-taxonomy and http://datazone.birdlife.org/sowb/spotseabirds#:~:text=Seabirds%20are%20a%20taxonomically%20varied,part%20of%20their%20life%20cycle. (both last accessed: 02.09.23)

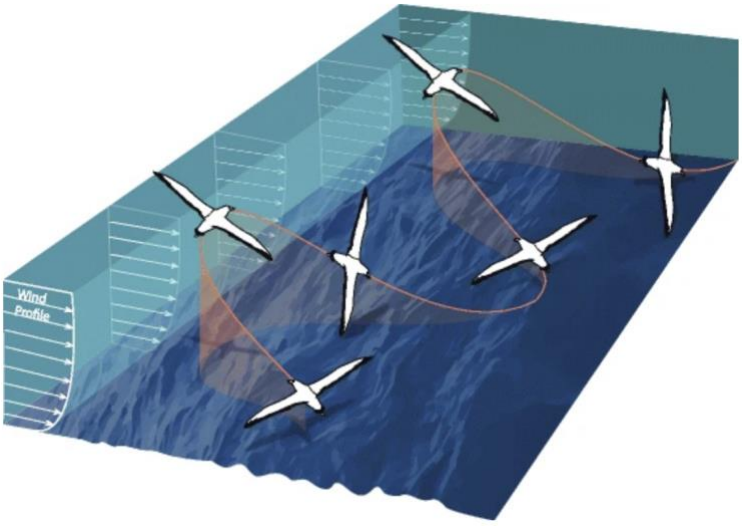

Figure 1 - A diagram of the dynamic soaring technique. Reproduced from Richardson et al. 2018 under a Creative Commons Attribution 4.0 International License https://creativecommons.org/licenses/by/4.0/

Seabirds are drawn away from these windy, oceanic worlds annually or biannually towards land to find a partner, breed, incubate, and rear their chicks. They often site their colonies and breeding timing in relation to the spatial and temporal rhythms of their marine prey species and tend to exhibit site-fidelity: returning to the same breeding sites each year (Wooller et al. 1992). This exposes the birds not only to changing environmental conditions, but also to the ecological effects of those changes. Factors influencing the spatial distribution, abundance, and the timing of the appearance of their prey also influence the birds through the transfer of energy through food webs. Their responses vary from switching prey species to large-scale abandonment of their chicks and colonies in search of food (Cairns 1988). Their gregarious gatherings at the coast are also what seabird ecologists John Piatt and colleagues (2007, 200) call "a convenient occurrence" for scientists looking to study these beings and their oceanic environments. And studied they have been, more so than any comparable group of marine organisms (Croxall et al. 2012a). It is precisely for these reasons – the wealth of scientific data and knowledge amassed about seabirds, coupled with their intimate bodily correspondence with marine and atmospheric environments – that these birds are so compelling to scientists as sentinels of ocean change.

In reviewing existing social scientific literatures on environmental sentinels at the outset of this research, it became clear that their focus was often bounded to particular

geographical sites and localised instances where nonhumans signal an emerging environmental threat – for instance, fish and water abstraction in a river delta (Lakoff 2016); farmed chickens and avian influenza in Hong Kong and southern China (Keck 2015); and mussels and local water quality (Gramaglia and Sampaio da Silva 2012). These studies significantly guide my own inquiry, but in focusing on seabirds my desire is to explore how animals are being integrated into sensing and governing practices occurring across more expansive geographies and temporalities and to pluralise engagements with environmental sentinels in the ways I outline in Chapter Two. In particular, the notion of sentinel geographies is intended to illustrate how sentinels come to signal warnings or threats not just in their immediate milieux, but also in interconnected environmental systems in conditions of crisis. There were of course other trajectories I might have followed in doing so – for example, marine mammals are also used as sentinels of ocean changes taking place at large temporal and spatial scales (see Hazen et al. 2019; Moore 2008). The decision to focus on seabirds was informed by the frequency with which scientists and conservationists refer to them as sentinels (sentinel is a clear actor's category here), and a sense that they afford other opportunities that marine mammals, for example, do not. Their unique straddling of terrestrial, oceanic, and atmospheric worlds, for instance, enables thinking across different existing *liminal* understandings of the ocean; as unknowable and ungovernable but, nevertheless, subject to myriad knowledge and governance practices (Lehman 2019; 2020); as distinctive from but ultimately connected to terrestrial spaces and human worlds (Alaimo 2012; Ingersoll 2016); and as in continuous material transformation and extension, never neatly confined to the space beyond the shore's edge (J. Anderson 2012; Bear 2013; Peters and Steinberg 2019).

1.4.2. Albatross stories

And I had done a hellish thing,
And it would work 'em woe:
For all averred, I had killed the bird
That made the breeze to blow.
Ah wretch! said they, the bird to slay,
That made the breeze to blow!

- Samuel Taylor Coleridge (1798), 'The Rime of the Ancient Mariner' (lines 91-96).

In this thesis I ferry back and forth between discussions of seabirds in general and a narrower focus specifically on albatrosses. My reasons for doing so are as follows. It is well documented in research and conservation practice that certain species attract more interest and concern than others, by way of their enchanting, awe- or curiosity-inducing affordances, or "nonhuman charisma" (J. Lorimer 2007; see also Bowker 2000; E. A. Macdonald et al. 2015). Without seeking to reproduce this uneven valuation of the nonhuman world or affirm the terms according to which it takes place, I am nevertheless interested in albatrosses in large part because other people – scientists, conservationists, certain publics, and policy-makers – are, too. As I discuss throughout the thesis, this interest is tantamount to their importance as environmental sentinels. A first manifestation of this appears in albatrosses' outsized representation in scientific research on seabirds. They are some of the best studied seabirds and have been used as the animal 'model' for testing a range of new biologging technologies (see Weimerskirch 2018). Wider interest is directed particularly towards albatrosses' large size (some species weigh up to 10kg and have wingspans over 3 metres, the longest of any bird); extreme mobilities (albatrosses travel hundreds or thousands of kilometres in single foraging trips at high speeds propelled by supra-oceanic winds (Richardson et al. 2018); long lives (the world's oldest known bird is a Laysan albatross nicknamed 'Wisdom,' who is at least 71 years old); and lasting pair bonds and courtship rituals, which will be familiar to audiences of popular nature documentaries where they have often been portrayed in anthropomorphic ways.

Figure 2 - Juvenile wandering albatrosses engaged in a courtship display. Reproduced from Weimerskirch 2018 under a Creative Commons Attribution 4.0 International License. https://creativecommons.org/licenses/by/4.0/

Contemporary interest in albatrosses (particularly amongst citizens of countries in the Global North) also derives from their surprisingly rich Anglo-European cultural history.[5] They appear amongst the writings of James Cook, Charles Baudelaire, Herman Melville, and others, while perhaps the most famous literary reference to the birds is Samuel Taylor Coleridge's poem 'The Rime of the Ancient Mariner' (1798)(see Barwell 2007; 2013). Indeed, it is rare to find popular anglophone writing about albatrosses which does not refer to Coleridge's poem, such is its perceived significance to public perceptions and understandings of albatrosses (Barwell 2007; Doughty and Carmichael 2011; Safina 2002; Tickell 2000).[6] In summary, the bodily and ecological affordances of albatrosses, coupled with their cultural significance, afford them outsized significance in scientific research, conservation practice, and popular

[5] I suggest this is surprising because of albatrosses' distributions in the Southern Hemisphere, but it becomes less so when we consider the imperial histories of European nations (see Chapter Four). Less surprising, perhaps, is that the birds also feature in the stories and mythologies of cultures which have been more regularly in embodied contact with them – such as the Maori in Aotearoa-New Zealand, Indigenous Hawaiians, and the Ainu in Japan (see Barwell 2013; Osterlund 2016).

[6] Seabird ecologist William "Lance" Tickell, one of the instigators of systematic scientific study of albatrosses in the late 1950s, has referred to this as 'the mariner syndrome' (Tickell 2000).

imaginations compared with many other seabird species. This is one reason this thesis focuses especially on these seabirds.

The second reason pertains more to research design. Seabirds are used as sentinels for phenomena ranging from mercury contamination in the Arctic (Fort et al. 2016) to plastic pollution in the Southern Ocean (Phillips and Waluda 2020) and the surveillance of illegal fishing activities (Weimerskirch et al. 2020). A broad focus on seabird sentinels then risked proliferating beyond a manageable size for this research. Choosing to focus primarily on albatrosses was a bounding decision informed by the discussion above and their traversal of particularly extensive spatialities and temporalities even compared with other seabirds. A further bounding decision was to organise the research around a particular environmental governance issue – seabird bycatch in commercial fisheries. This presents one of the greatest conservation threats to seabirds, particularly to albatrosses (Phillips et al. 2016), and I focus on it here to offer an in-depth exploration of the relations between environmental sentinels and ocean governance. In pursuing this primary focus, other examples of how seabirds act as sentinels – such as those noted above – are inevitably marginalised. These might have led to slightly different conclusions, but I seek to counter this in Chapter Four through a broad analysis of the histories of sensing with seabirds, and in Chapter Six through a discussion of relations between albatrosses and plastic pollution.

Seabird bycatch entails a conglomeration of deadly interactions between birds and fishing vessels, including collision with trawler cables, drowning in fishing nets, and becoming caught on baited long-line hooks as they are unspooled from boats. Estimates put the upper range of seabird mortality in long-line fisheries alone at 320,000 birds annually (O. Anderson et al. 2011). Albatrosses make up a disproportionately large number of the total birds killed this way because of their propensity to follow boats and scavenge food, their bullishness over smaller seabird species when feeding, and their large mouths which mean they more easily ingest longline hooks (Phillips et al. 2016). Bycatch became a serious albatross conservation concern in the late 1980s when many species' populations began to decline rapidly following decades of sustained growth in Southern Ocean commercial fisheries for highly valued species like southern bluefin tuna and Patagonian toothfish (Brothers 1991; Tuck et al. 2003; Weimerskirch and Jouventin 1987). Now, 15 of 22 albatross species are considered

threatened by the IUCN (2020), with bycatch the principal driver of this endangerment. Effective mitigation measures exist to address this threat (Agreement on the Conservation of Albatrosses and Petrels 2021), but regulatory and practical uptake of these measures has been slow (see Gilman 2011; Gilman et al. 2016).

Focusing on seabird bycatch positions this thesis as a contribution to discussions around fisheries governance as well as environmental sentinels. This is especially the case in Chapters Five and Seven.[7] In particular, the thesis is interested in the *digital transformations* in fisheries governance that albatrosses and other seabirds are caught up in. Recent high-profile coverage of the global fishing industry – for instance, the Netflix documentary 'Seaspiracy' (2021) and journalist Ian Urbina's (2020) book 'The Outlaw Ocean' – has painted an image of an industry characterised by a culture of secrecy and widespread regulatory noncompliance and illegality. Conservationists view this as one of the key challenges facing the implementation of bycatch mitigation measures and, by implication, seabird and albatross conservation *tout court*. Recent 'smart ocean governance' initiatives, increasingly co-ordinated by non-state actors, take aim at the lack of oversight of the fishing industry by pursuing enhanced digital surveillance of the maritime domain. These are guided by a shared conviction that "data renders the oceans, and the activity therein, visible to policy…[and] that data creates, and is essential for, transparency" (Drakopulos et al. 2022, 2; see also Bakker 2022; Gray 2018; Ritts and Simpson 2022). In new forms, made more interoperable, and collected in greater quantities across larger spatial and temporal scales, data are held to improve the decision-making capacities of fisheries managers, offer greater oversight to enforcement agencies, and deliver benefits to industry through increased operational efficiency and access to markets demanding traceable, sustainably-harvested seafood (e.g. Michelin and Zimring 2020; Kroodsma et al. 2018). Social scientists have approached these claims with caution, recognising the potentials for digital technologies to deepen the uneven exercise of power and control in environmental governance (Drakopulos et al. 2022; Toonen and Bush 2018). This thesis contributes new understandings of the practical implications of such 'smart ocean' approaches to fisheries governance through an attention to the cases of

[7] A detailed account of the historical relations between albatross conservation and commercial fishing activities is not provided here but is offered in Robin Doughty and Virginia Carmichael's book 'The Albatross and the Fish: Linked Lives in the Open Seas' (2011).

'on-bird' and 'on-board' fisheries surveillance outlined in the thesis roadmap below and explored in Chapters Five and Seven.

1.5. Research questions and contributions

The aim of this thesis is to explore, via an empirical study of seabird sentinels, the more-than-human technologies, collectives, and practices that are becoming implicated in knowing and governing the Anthropocene's turbulent ecologies. Its focus is on ocean ecologies in crisis and the novel modes of knowledge production and governance which are emerging in response. To address this aim, I have developed four research questions which correspond roughly to the four empirical chapters of the thesis:

1. How and why have seabirds become sentinels?
2. How are seabird sentinels used to govern ocean space and with what consequences?
3. How do sentiments shape how seabirds act as sentinels?
4. How are the promises of digital ocean governance complicated in practice and with what consequences for seabirds and marine ecologies?

In answering these questions, the thesis makes a series of important contributions to geographical literatures, which are highlighted throughout the text. These are: a proposition for **sentinel geographies** as a novel field of geographical inquiry, specified through the conceptual framework developed in Chapter Two; the concepts of '**operational sentinels'** – which concerns how animal sentinels are deployed directly as tools for new real-time, responsive forms of governance associated with what Andrew Lockhart and colleagues (2023) term 'operational ecologies' – and '**sentinels of sentiment'** – which captures the important affective, emotive dimensions to the signalling work done by sentinel animals in conservation practices, contrasting with existing accounts focusing predominantly on scientific logics associated with sentinels; and the notion of '**selective transparency**' which accounts for how ocean governance actors affirm transparency as a key governance outcome enabled by digital technologies and the data they generate, even as they strategically shape what is rendered in/visible by these technologies.

In addition, this research is also conceived as an intervention into the fields it studies – seabird conservation and fisheries governance – and my analysis raises a set of considerations for practitioners in these fields. Geographers have noted how the deployment of digital technologies for environmental governance purposes often outpaces establishment of frameworks governing their use (Sandbrook et al. 2021; Toivonen et al. 2019). As I discuss in Chapter Five, animals are increasingly enrolled in digital environmental surveillance without clear and context-specific ethical and regulatory frameworks governing their use for these purposes. I call for conservation practitioners to actively engage in developing such frameworks, which should expand beyond existing efforts to define technical guidelines for the size, weight, shape, etc. of digital devices deployed on animals (see Vandenabeele et al. 2012; Rory P. Wilson et al. 2019). A similar consideration relates to the fisheries electronic monitoring (EM) technologies I discuss in Chapter Seven. These are being deployed to improve transparency and accountability in the fishing industry, but the ways in which this is happening risks key ecological effects of fisheries – like seabird bycatch – being largely ignored. They also face resistance from fishers based on privacy concerns and their exclusion from decision-making processes. This research thus contributes to ongoing conversations amongst researchers and practitioners about what specifically is made visible by digital technologies in environmental governance, how these partialities might be more openly communicated, and where more participatory approaches to the design of new governance interventions might be developed (Drakopulos et al. 2022; Holm et al. 2020; Toonen and Bush 2018).

1.6. Thesis roadmap

The structure of this thesis is as follows. In Chapter Two I establish the conceptual framework for the thesis. Sentinel geographies is positioned as the main conceptual contribution and, by elaborating on this, I propose environmental sentinels as valuable subjects of geographical inquiry and develop a specific and novel understanding of sentinels that is appropriate to their application in environmental contexts. I put forward a three-part understanding of environmental sentinels in terms of devices – categorised as sentinel species, sentinels of sentiment, and operational sentinels – as well as more-than-human collectives and practices.

This understanding bridges across existing work on sentinels in the social and natural sciences and extends it in new directions. The conceptual framework of the thesis is further developed in three ways. First, I review and bring together literatures concerned with the ocean across geography, political ecology, STS, and histories of science to account for the environment and contexts of motivation in relation to which seabirds become sentinels. Second, I turn to an emerging literature in digital environmental geography exploring the digital mediation of human-nonhuman relations which is essential to understanding how sentinels are known and mobilised for environmental governance purposes together with various digital technologies. Lastly, I situate the conceptual concerns of the thesis in relation to more-than-human geographies and articulate the contribution of a more-than-human approach to researching environmental sentinels.

Chapter Three describes the methodological orientations and methods through which the aims and research questions of this study have been pursued. It situates the research partly within the context of the COVID-19 pandemic and describes how this shaped the approach taken, and details the mix of document analysis, semi-structured interviews, participant observation and creative and online methods used in the research. The processes of generating and analysing research materials, and the temporalities of these processes, are discussed, alongside reflections on practising ethical research.

The first empirical chapter addresses the question: *"how and why have seabirds become sentinels?"* It focuses on the monitoring and tracking of seabirds from the mid-20th century to the present, contextualising the chapters that follow and presenting its own contribution to the histories and historical geographies of ocean science and ornithology. I show how seabirds have been reconfigured as sentinels through their enrolment in international, data-driven observational networks that are at once about understanding birds and about monitoring changing marine environments. This reconfiguration has been driven by a recognition of the environmental information seabirds integrate into their bodies and, more recently, shaped by the kinds of digital devices that can be attached to them. As scientists have developed new ways of knowing oceans using birds, and the political economic contexts of ocean research have been in flux, new relational avian identities have emerged. Drawing insights from literatures in the histories of science and historical

geography attentive to the changing character of environmental monitoring, ocean science, and ornithology in the latter half of the twentieth century, I offer accounts of three ways in which seabirds have been enrolled in different scientific projects - as populations, samplers, and platforms. Each offers different insights into the processes and logics according to which animals are designated as sentinels and, together, they position seabird sentinels as multiple and emergent from interactions between the affordances of the birds themselves and the political economic contexts within which seabird science takes place.

In Chapter Five, I address the question: *"how are seabird sentinels used to govern ocean space and with what consequences?"* I consider a prominent example of how seabirds as platforms are being operationalised to govern ocean spaces in new ways through an approach I term 'on-bird surveillance.' This example, the Ocean Sentinel project, is a collaborative initiative led by the Centre for Biological Studies of Chizé which has developed new biologging technologies for deployment on albatrosses in order to detect illegal fishing vessels in the southern Indian Ocean in real time. Through collaborations with government agencies in the French overseas territories these sentinel albatrosses have been used to control illegal fishing activities, lending them the title of 'albatross cops' in media coverage. This on-bird surveillance technique is discussed in relation to existing approaches to mapping albatrosses' overlaps with and risk of bycatch in commercial fisheries, intended to inform conservation measures, and an emerging set of 'dynamic ocean management' techniques which seek to govern the ocean in responsive, real-time ways (Maxwell et al. 2015). I explore how on-bird surveillance differs from these other approaches and mobilise the concept of 'operational sentinels' to distinguish on-bird surveillance from other uses of animal sentinels that social scientists have engaged with, and to specify the mode(s) of power at work through this technique. In the latter parts of the chapter, I trace the implications of this approach for the birds themselves, for relations between scientists, conservationists, fishers, and fisheries governance actors, and for understandings of surveillance as an appropriate marine governance technique. Showing that similar approaches are becoming more widespread, I conclude by proposing directions in research and practice for better understanding and managing their effects.

Chapter Six turns from how albatrosses are operationalised for surveillance purposes towards how they are used by various actors as vehicles of sentiment to cultivate care about environmental issues amongst different audiences. It responds to the question: *"how do sentiments shape how seabirds act as sentinels?"* Here, the charismatic affordances of albatrosses discussed earlier in this Introduction come into play. These are mobilised via different mediations to communicate threats in albatrosses' environments – from fisheries bycatch to plastic pollution – in ways that contrast with the scientific-reason-based logics commonly associated with animal sentinels discussed in the preceding chapters. This chapter thus broadens engagements with animal sentinels by attending to affect, emotion, and feeling (captured imperfectly here by the term 'sentiment') as important to the signalling work done by sentinel animals as well as the agencies these animals come to have in environmental governance contexts. I suggest albatrosses are one example of 'sentinels of sentiment' – beings which are made to signal threats in their environment and configure responses through their appeals to sentiment – and elaborate on this concept through three episodes connected by their significance as popular albatross stories of the early 21st century. Each of these evokes a different kind of sentiment, involves different animal bodies and spaces of encounter, and has a distinctive political function. In conclusion, I consider the tensions between the different ethical orientations and environmental politics fostered in these different instances, and how these interact with scientific and conservationist logics.

In the final empirical chapter, my attention shifts to the 'on-board' dimensions of digital fisheries monitoring and governance, building upon the 'on-bird' dimensions discussed in Chapter Five. I address the question: *"how are the promises of digital ocean governance complicated in practice and with what consequences for seabirds and marine ecologies?"* Rather than acting as lively surveillance agents, the birds I discuss here appear dead as bycatch aboard fishing vessels, raising a different set of concerns. I trace recent transitions towards monitoring fisheries with on-board electronic monitoring (EM) technologies, which promise timely, comprehensive, and cost-efficient data collection and increased regulatory compliance – making problems such as seabird bycatch both more visible and governable. I discuss how these promises – common to a wider set of digital ocean governance transformations - are complicated by the glitches and frictions (discussed in section 3.3 of

Chapter Two) associated with the rollout of these technologies, some of which are deliberately fostered into being by actors resisting their own surveillance.

As I outline in Chapter Two, discussions of digital transformations in environmental governance frequently adopt either a strongly optimistic or critical position, and this chapter offers a contrary reading between these positions. I divide my analysis according to glitches and frictions which occur upstream of deploying EM technologies on vessels, during their deployment where they interact with the on-board and marine environment, and downstream where the data these technologies produce is analysed by humans and machines. I propose the concept of 'selective transparency' to account for how good governance based on transparency is performed at these different stages while strategic practical interventions are mobilised to influence what is and is not made visible by digital monitoring technologies. Seabirds are highlighted as a casualty of selective transparency and, in light of this, the concept's import to discussions of 'smart' environmental governance approaches is discussed. This chapter may be read as a diversion from the thesis' concern with seabird sentinels but develops this concern by attending to a context where (dead) seabirds *do not* make good sentinels, providing an opportunity to specify the conditions under which they do.

Chapter Eight reiterates and summarises the key arguments and conceptual contributions made in this thesis. It specifies these in relation to the research aim and questions set above, as well as the conceptual framework developed in Chapter Two concerning 'sentinel geographies.' Finally, I reflect on a series of 'paths not taken' by this research and identify promising directions for future research, including an enlarged role for seabirds in geographical engagements with the ocean and 'avian anthropocenes' (Turnbull and Wrigley 2023), new approaches to studying wildlife tracking and monitoring in critical animal studies, and possibilities for future sentinel geographies research.

Chapter Two

Conceptualising sentinel geographies

2.1. Introduction

This chapter draws on literatures in geography, anthropology, science and technology studies, and the environmental humanities, to put forward "sentinel geographies" as a novel field of geographical enquiry. Sentinel geographies – which offers the central conceptual contribution of this thesis – seeks to address three things. First, I seek to position environmental sentinels as important subjects of geographical enquiry. My proposition is that these sentinels afford novel ways to account for the changing more-than-human collectives, technologies, and practices that are being called upon and fostered into being to know and govern the Anthropocene's turbulent ecologies. Secondly, then, sentinel geographies entails a specific and novel understanding of sentinels which is appropriate to their diverse applications in environmental, and particularly conservation, contexts. This builds on and differs from existing work which has considered animals as 'sensors.' To this end, this chapter develops an understanding of environmental sentinels in terms of devices (including sentinel species, sentinels of sentiment, and operational sentinels), collectives, and practices. This tripartite understanding bridges across existing work on sentinels in the social and natural sciences and extends it through consideration of sentinels as operational – that is, put to work as tools for governing environments and human activities therein; as distributed across more-than-human collectives and performed through practices; and as figures for communicating environmental changes in ways that appeal to affect, emotion, and feeling.

Lastly, sentinel geographies is put forward as an approach which draws together often disparate fields of inquiry in order to understand the new ways of knowing and governing environments that sentinels enable. This is achieved through the conceptual framework developed in this chapter. This involves, first, attending to environments and the contexts of motivation which shape *why* they are known and governed in particular ways. My empirical focus in this thesis draws me particularly to the ocean here, and literatures in geography, political ecology, STS, and the history of science which have developed new ocean ontologies, accounted for the emergence of the ocean as an object of knowledge and governance, and attended to the power relations at play in different kinds of human-ocean entanglements. This framework entails a particular understanding of *how* these ways of knowing and governing are achieved. This orients me towards an emerging literature in 'digital

environmental geography' which explores the digital mediation of human-nonhuman relations and the implications of this for environmental knowledge production and governance. These ways of knowing and governing are understood as more-than-human, achieved together *with* nonhuman technologies and animals. This anchors the conceptual concerns of this research in relation to the field of more-than-human geographies, and I seek to articulate what a more-than-human approach to researching sentinels offers.

Taken together, these three elements developed in this chapter – i) a proposition that environmental sentinels are important subjects of geographical enquiry, ii) a conceptualisation of sentinels appropriate to this enquiry, and iii) a broader conceptual framework within which this enquiry is situated, and which frames the contributions it seeks to make – lay the foundations for the empirical chapters which follow.

2.2. Sensing the oceans

The ocean has become a 'sensor space,' surveilled from above and within by networks of in-situ, robotic, and satellite-based digital sensing technologies.[8] With these technologies, a majority of contemporary scientific knowledge of the ocean and its ecologies is composed. Practices of ocean sensing enable particular ontological claims about the ocean and are underpinned by and facilitate particular kinds of politics. As geographer Jessica Lehman (2020, 166) observes, "knowledge, technology, and geopolitics are woven together in how questions of ocean governance are framed and, potentially, answered." In seeking to understand seabird sentinels and their implications for ocean governance, this research draws and builds on a recent proliferation of work in human geography and related disciplines focused on the ocean and ocean sensing and governance practices. This section identifies the relevant strands in that work for the purposes of this research and, relatedly,

[8] Of course, this is to approach the ocean from the perspectives and infrastructures of (predominantly) Western technoscience. Alternative understandings might approach the ocean from a more dwelt perspective as a space inhabited and storied by Indigenous cultures, for instance, whereby ways of knowing the ocean continue to emerge from embodied experience. The ocean as a 'sensor space' is not used here to preclude the existence of other kinds of ocean spaces associated with these alternative understandings, which Karin Amimoto Ingersoll terms 'seascape epistemologies' (Ingersoll 2016).

highlights a series of important "contexts of motivation" (Oreskes 2003) which have shaped the contemporary practices and politics of sensing the ocean.

2.2.1. The turbulent ocean

From a relative silence on topics pertaining to marine spaces (Bear and Eden 2008), the critical social sciences and humanities have emerged in the past decade as more prominent voices in scholarly and public discussions about the ocean, characterised by some as a "blue" or "oceanic turn" in these disciplines (see Alaimo 2019; Braverman and Johnson 2020; DeLoughrey 2017). This turn has been motivated, in part, by an emerging understanding of the ocean as a powerful, dynamic force shaping the planetary system. Oceanographers increasingly speak in unsettling terms of the ocean as a highly variable, non-linear, complex system with destabilising effects on the global climate, one which exhibits 'widespread disparities' from their predictive models (Su et al. 2023). Along with other markers of change such as collapsing fish stocks and plastic accumulations, such understandings have propelled the ocean to the forefront of discussions about uncertain, potentially catastrophic, planetary futures. To capture these relations between the ocean and the planetary, scholars have proposed such terms as the AnthropOcean (Brugidou and Fabien 2018), Anthroposea (Anand 2023), Blue Anthropocene (Fish 2022), and Thalassocene ("a pressure the inhuman ocean exerts on all human histories, inimical to the human lives it helps structure") (Mentz 2015, xix).

Whilst oceanographers often express a normative ambition for comprehensive monitoring of the oceans and a desire to overcome the epistemological challenges this realm presents to scientific knowledge production, geographical scholarship is more engaged with the indeterminacy and otherness of the ocean as a generative intellectual provocation (see Forssman 2017; Lehman 2021). From geographers Philip Steinberg and Kimberley Peters' (2015, 247) "wet ontology," to media studies scholar Melody Jue's (2020, 17) "milieu-specific analysis," and anthropologist Stefan Helmreich's (2015, 186) "theory underwater," the impetus of much of this work has been dual. First, to develop new ways of accounting *for* the ocean and marine life as subjects of social inquiry which challenge the certainties and reductivism of technoscientific knowledges or the resource framings of, for instance,

economists and fisheries scientists; and, second, to draw on the ocean's voluminous, turbulent, excessive characteristics as incitements to destabilise and rethink theories and concepts with their origins in terrestrial modes of thought and practice.

2.2.2. The politics of ocean volumes

In pursuing these two related projects, these literatures form part of wider scholarship seeking to trouble cartesian understandings of space, to develop novel volumetric, three-dimensional understandings of the operation of power (see Billé 2020; Elden 2013), and to account for the "force of the elemental" in social and political life (Adey 2015). Geographers Sasha Engelmann and Derek McCormack (2021, 1420) helpfully summarise that the "elements bring into focus the transformative agency of anthropogenic activity in relation to the composition of the Earth at the same time as they provide insistent reminders of the limits of this agency. They hold together while also holding open possibilities for thinking through materialities, affects and sensations across scales from the atomic to the planetary." Literatures on volume, moreover, attune us to how scientific knowledge production is crucial to the governance of marine space according to logics of security, reflecting what Franck Billé (2020, 5) calls "the three-dimensional nature of modern territorial control." Although they are rarely in explicit conversation, literature in the geographies and histories of science offer important context to these intersections between knowing and governing marine spaces, and the interests that have configured them in particular ways. Historian Etienne Benson (2012, 844), for instance, has shown how state agencies afforded greater priority to physical environmental scientists – meteorologists and oceanographers – in the early development and applications of new Earth observation satellites. This was to the detriment of biologists interested in using these systems to track wildlife, and shaped visions of the global environment in terms of a "volume of flows" in contrast to a "web of life." Historian of science Naomi Oreskes (2003; 2021) situates these visions in terms of the configuration of oceanographic research post-World War II by US naval funding and interests. With its interest in the propagation of sound and machinery through marine spaces, the physical dynamics of the ocean as a volumetric space often gained most military interest and funding when seen "through the crosshairs of national security" (Oreskes 2003, 697).

These scholars have thus pointed out, directly or indirectly, that the very ability to evoke the oceans in the voluminous, turbulent, and planetary terms that literature in the 'oceanic turn' often does rests upon advances in post-World War II oceanography and Earth System Science (ESS), which are inseparable from "imperial networks refracted through the politics of the Cold War" (Lehman 2019, 619; see also Oreskes 2003; 2021). Eva Lövbrand and colleagues (2009, 10) observe that it is through the developing toolkit of scientific earth observations – "closely tied to matters of national security and military surveillance" - that the planet as a coupled human and ecological system has emerged as "a thinkable and governable domain" (p.8). A growing body of work is thinking across these understandings of the ocean as a dynamic volumetric space and a governed and governable domain shaped through historically specific processes and ways of knowing (see Braverman and Johnson 2020; and Helmreich in Avanessian et al. 2021 for aligned approaches). In particular, in this thesis, I draw on work in the traditions of political ecology and earth systems governance, which offer insight into the changing operations of power in marine governance, the effects of historical processes on contemporary marine governance discourses and practices, and an attention to questions of (in)equality and (in)justice (see N.J. Bennett 2019; Campbell et al. 2016). This work, elaborated upon further in the following sections, is especially pertinent to Chapters Five and Seven where I focus on digital transformations in contemporary fisheries governance.

2.2.3. The frontier logics of ocean sensing

In parallel to engagements with the ocean as a geopolitical volume, the decades following World War II saw the ocean reimagined as a frontier for industrial expansion (see Rozwadowski 2012), stimulating the rapid industrialisation and geographical expansion of fisheries. This has been described as "a frenzied free-for-all" (Hubbard 2014, 374), and spurred the development of modernist forms of fisheries management, and the discipline of fisheries science, to govern this fishing effort. Political ecologists have described how these disciplines understand the ocean according to what Gíslí Pálsson (1998) describes as "the aquarium," a regime promising rational, totalising knowledge and control of marine resources (see also Drakopulos 2019). Moreover, they have situated them in the context of geopolitical motivations, state subsidies, and the expansion of capitalist relations into new

ocean spaces (Campling and Havice 2014; 2018; Finley 2011; Silver et al. 2022). Where natural scientists have illustrated that fisheries management regimes are failing marine ecologies through overexploitation of fish 'stocks' and bycatch of non-target species (see Cullis-Suzuki and Pauly 2010; Gilman et al. 2014), political ecologists and scholars of ocean governance have illustrated how fisheries science, as a tool of government, is deeply implicated in these failings (Hubbard 2014; Finley and Oreskes 2013; Jennifer J. Silver et al. 2022). Anthropologist Jennifer Telesca (2020, 3) goes further to identify the implication of fisheries science in a "predatory exterminatory regime of value" which configures the operation of tuna fisheries management organisations, which, when we come to understand the significance of these actors to seabird conservation efforts in Chapters Five and Seven, becomes a valuable and concerning insight.

These "contexts of motivation" informing the production of scientific knowledge about the ocean – military/geopolitical and extractive/industrial expansionist – are, of course, interlinked. Geographer Noella Gray (2018) suggests both express a "frontier imaginary" (p.257) which paradoxically imagines marine space as vast and empty (characterised by physical dynamics but devoid of life) and yet full of abundant and exploitable resources (and military targets and threats). These, as noted above, are two powerful characterisations which geographical engagements with the ocean have worked against. Gray also identifies a recent shift in this frontier mentality, "from resource frontier to conservation and science frontier" (p. 258). Here, from the perspectives of scientists and conservationists, the ocean – irreducible to its physical dynamics or to resources – is both under-studied and under-governed (see Drakopulos et al. 2022). This provides an important and well-documented contemporary context of motivation for ocean sensing and governance practices, which is not, as Steinberg (2008, 2080) argues, entirely separate from those described above: "marine environmentalism […] extends beyond the groups usually associated with the conservation of species and ecosystems to include commercial interests, military strategists, and neoliberal policymakers." Novel digital sensing practices are emerging whose aims have been understood to combine biodiversity conservation with the interests of marine industry actors and the "capitalist environmental state" (Ritts and Simpson 2022, 3; see also Bakker 2022; Drakopulos et al. 2022), and which support militarised forms of conservation intervention (Fish 2022; Urbina 2020). These are marine manifestations of what others have identified as

the increasing securitisation and militarisation of conservation via intensified surveillance and policing (Duffy 2014; Kelly and Ybarra 2016; Masse 2018), which reify the promise of totalising vision and control expressed by Pálsson's 'aquarium.'

2.2.4. Digital transformations in ocean governance

Understanding the shifting character of *these* sensing practices and their ocean governance implications, by way of the literatures discussed above, is a central concern of this research. In particular, this project contributes to a growing body of work in geography, political ecology, STS, and earth system governance which traces the implications of digital transformations in ocean governance (Bakker 2022; Drakopulos 2019; Drakopulos et al. 2022; Gray 2018; Ritts and Simpson 2022). Optimistic accounts, generally beyond the bounds of this work, see in these transformations a promise of a prosperous common human future linked ever more closely with the ocean as a space of scientific advancement and sustainable resource exploitation, disclosed for instance by the powerful imaginary-cum-policy-framework of the 'blue economy' (for some critical perspectives, see N. J. Bennett et al. 2021; Mallin and Barbesgaard 2020; Silver et al. 2015). By contrast, the extant literature in geography and related disciplines predisposes us to view these practices in terms of "their distancing and abstracting views that can make nature exponentially more available to the uses of capital and empire" (Lehman 2020, 165).

As Lauren Drakopulos and colleagues (2022, 2) observe, there is a need to move beyond these binaries of celebration and critique towards more situated empirical understandings. Moreover, I identify an additional need – in line with geographer Rachel Squire's (2020, 9) call for scholarship on marine geopolitics to become "more attuned to the lives, bodies, and fleshy affordances of animals" – to enrich existing accounts by attending to the liveliness of marine ecologies and the affordances of animals as they are entangled with these ocean governance transformations. These are two key contributions I seek to make through this research, and I suggest that a focus on animal sentinels and their implications for ocean governance offer a particularly compelling case through which to do so. Before this chapter turns specifically to animal sentinels, however, I first outline the relevant approaches

developed by digital environmental and more-than-human geographers, and others in related fields, which inform my own conceptual framework.

2.3. Digital environmental geography

2.3.1. Frameworks

Human-nonhuman relations are increasingly mediated by digital technologies (see Turnbull et al. 2022). This, as we began to see above, has varied implications for how we live together in shared worlds. Before exploring this in greater detail, a brief note for orientation on 'the digital', digitisation, and digitalisation. The meaning of these terms is subject to ongoing debate. Digital geographers James Ash and colleagues' (2018, 26) definition of 'the digital', which follows from those proposed by others like media studies scholar Peter Lunenfeld (2000), affords suitably broad scope for this study: "material technologies characterized by binary computing architectures; the genre of socio-techno-cultural productions, artefacts, and orderings of everyday life that result from our spatial engagement with digital mediums; and the logics that both structure these ordering practices as well as their effects […and] digital discourses which actively promote, enable, secure, and materially sustain the increasing reach of digital technologies." Felix Creutzig and colleagues' (2022) recent definitions of digitisation as the reduction of information to the sequences of zeroes and ones that constitute binary code, and digitalisation as the widespread deployment of digital information and communication technologies across varied contexts, align with how I use these terms.

Following a broader disciplinary 'digital turn' (Ash, Kitchin, and Leszczynski 2018), geographers now have at their disposal a range of related analytical frameworks for making sense of digitally mediated human-nonhuman relations (Büscher 2013; Cubitt 2017; McLean 2020; Nelson, Hawkins, and Govia 2022; Nost and Goldstein 2021; Parikka 2014; Taffel 2021; Turnbull et al. 2022; van der Wal and Arts 2015; for an overview see Verma 2021). These are variously attuned to the ways in which digitalisation and digitisation: are material processes, underpinned by physical infrastructures and implicated in extractive economies and the production of waste and other environmental harms (see Gabrys 2011; Parikka 2014; Taffel

2012); shape the production of scientific knowledge and facilitates particular understandings of environmental processes and nonhuman lifeworlds (see Benson 2010; Edwards 2010; Lehman 2018); enable human-nonhuman encounters, both commodified and convivial, which are novel but no less 'real' than their offline counterparts, producing new affective relations and embodiments (see McLean 2020; Prebble, McLean, and Houston 2021; Turnbull et al. 2022); and transform environmental governance and the uneven exercise of power and control over nonhumans (see Adams 2019; Bakker and Ritts 2018; Urzedo et al. 2023). It is now possible to speak of a 'digital environmental geography,' which combines these concerns, as a distinctive field of enquiry (see Lockhart et al. 2023).

2.3.2. Critical tendencies

A strong critical tendency remains amongst this work for what Agnieszka Leszczynski (2019, 190) terms a "techno-hysteria […] that exclusively equate[s] digital platforms with neoliberal corporatization and capitalist usurpation." For instance, Bram Büscher, a prominent voice in theorisations of the relations between new media and nature conservation, is quick in recent writing to associate debates about nature online with the entrenchment of platform capitalism[9], the commodification of nature, and the reification of structural dynamics causing environmental crises (2021; see also J. Lorimer 2022). Such observations are not unfounded. Indeed, what Bill Adams (2019, 338) refers to as a "digital reshaping of conservation ideas and practice," is characterised in part by the intensified use of digital devices like camera traps, drones, and satellites in new regimes of conservation surveillance. These promise to render ecological processes and human activities, hitherto invisible or partly obscured from the agencies that would manage them, visible and amenable to management. Yet, they also have the capacity to further militarised, coercive, and neoliberal modes of conservation (see Humle et al. 2014; Sandbrook, Luque-Lora, and Adams 2018; Sandbrook et al. 2021). A wider

[9] This is a term used to capture a form of accumulation "which is variously characterized by a [digital/online] platform-dependent interplay of speculative capitalization, a monopolistic telos, (at times) a divestiture from the owner- ship of tangible assets, the commodification of personal data trails, the flexibilization of labor, and the provision of a digital service that brokers access to other services and/or assets as a basis for monetization" (Leszczynski 2019, 192).

literature is replete with examples of where digital technologies further concentrate decision-making authority in environmental governance amongst experts and elites (Adams 2018), produce "hegemonising knowledge regimes" (Machen and Nost 2021, 555), and cement "neocolonial and racialized power structures" which reproduce injustices (Nost and Colven 2022, 23). In marine governance, Max Ritts and Michael Simpson (2022, 3) highlight that a fundamental belief of the 'capitalist environmental state', that "divergent social and environmental interests can be reconciled with expanding capitalist relations through the proper combination of technological innovation and well-crafted policy," is mobilised by and embedded within such 'Smart Earth' or 'Smart Ocean' technologies and approaches (see also Bakker and Ritts 2018).

2.3.3. Affirmative alternatives

Whilst there are plentiful grounds for making such claims, there is, equally, a danger of equating digital technologies and digitalisation with regressive politics through a combination of the empirical examples chosen and the conceptual frameworks used to analyse them. There is value in more affirmative readings which, whilst remaining mindful of the potentials for digital technologies to entrench extractive capitalism and socioecological inequalities, attend to where they might help to foster more progressive environmentalisms (see Hawkins and Silver 2017; Turnbull et al. 2023; von Essen et al. 2021). Indeed, the empirical chapters of this thesis attest that digital technologies incubate the potentials for many possible environmental outcomes and politics (see Drakopulos et al. 2022; Turnbull et al. 2022), neither straightforwardly negative, nor inherently positive – as per a celebratory "digital solutionist" outlook (see Kuntsman and Rattle 2019).

Wildlife tracking technologies, a central focus of Chapters Four and Five, offer an exemplary case: from the extant literature, we learn that these technologies may generate new awareness of animals' geographies (see Hodgetts and Lorimer 2018; Unnithan Kumar et al. 2022; Whitney 2014), data informing conservation policy and management decisions (see BirdLife International 2004b; Hussey et al. 2015; Verma et al 2016), and be used to engage publics in conservation (Adams 2020; Benson 2010). However, whilst GPS and radio tracking may be epistemologically useful for studying animals, critical scholarship has also noted that

these technologies are associated with reductive ontological claims about what animals are – reduced, in essence, to data points or GPS locations, devoid of embodiment and ecological context (see Adams 2020 on "digital animals"; Benson 2016a on "minimal animals"; and Bergman 2005 on "beasts with no body") – which enable particular kinds of biopolitical control (see Blair 2019; Collard 2018). This follows logics also noted in recent discussions of the datafication of human lives into "data selves" (Lupton 2019; see also Parry and Greenhough 2018; Wernimont 2019). In light of the diverse potentialities of these technologies and associated knowledge practices, this research cultivates a situated attentiveness to the kinds of animal and ecological relations that become knowable through them in specific instances (see the discussion of populations, samplers, and platforms in Chapter Four), and the forms of environmental decision-making this renders im/possible (see Chapter Five).

2.3.4. Glitch epistemologies

A final important concern in this thesis' engagement with digitally mediated human-nonhuman relations is summarised by Jonathon Turnbull and colleagues: "digital entanglement is always multiple, and partial: not everything can be neatly digitised, nor is digitisation a uniform process" (2022, 6). Just as scholarship in the 'oceanic turn' has documented the challenges marine spaces present to particular modes of knowledge production and theorisation, many worldly materialities and processes 'do not compute'; whilst being affected by digital mediation and computation, they are "irreducible to the imperatives and rationalities of platformization, algorithmic optimization, and datafication" (Leszczynski and Elwood 2022, 362; see also Mattern 2017). To account for this irreducibility, digital geographers have deployed the concept of the 'glitch.' For instance, Leszczynski and Elwood's (2022, 362) 'glitch epistemologies,' and Legacy Russell's (2020a; 2012) conception of the glitch as both error and erratum, both highlight the potentials for digital technologies to fail (in their intended purpose) and, in failing, to be reconfigured towards different, potentially more progressive, purposes (see Leszczynski 2019; Leszczynski and Elwood 2022; Maalsen 2023; Nunes 2012).

These literatures have thus far had little to say about digital transformations in environmental governance specifically, although Adam Searle and colleagues (2023, 3) have identified the possibilities they afford "for geographers to look beyond necessary, but insufficient, criticism of digitisation in the technonatural present, and to speculate on digitisation otherwise through affirmative scholarship." Here, they afford me a way to conceive of the interfaces where technologies, people, animal bodies, and environments meet in a manner that challenges a pervasive logic of 'measurementality' in contemporary environmental governance, and the power relations that this entails (Turnhout et al. 2014; see also Drakopulos et al. 2022). Measurementality, as used by STS scholars Esther Turnhout and colleagues, describes the celebration of transparency as a key principle of neoliberal environmental governance. As a concept recognising this turn to transparency but also problematising it, measurementality further highlights the implication of power relations in surveillance techniques aimed at generating transparency (Turnhout et al. 2014). Glitches, and related literatures alert to the material and sociocultural *frictions* which complicate the intended functioning of digital technologies, practices, or discourses (Aula 2019; Bates 2018; Edwards 2010), allow me to approach the concepts of measurementality and transparency in a novel way in my analysis of fisheries electronic monitoring technologies in Chapter Seven. The empirical material I present in this chapter works somewhat against the grain of existing affirmative approaches to the politics of frictions and glitches, however, by suggesting that although they challenge the logic of measurementality they *can* nevertheless simultaneously support the maintenance of status quo, ecologically damaging, fishing industry interests.

2.4. More-than-human sensing

2.4.1. More-than-human approaches

The digital mediation of human-nonhuman relations has important implications for the distributions of power and agency in environmental knowledge production and governance. Environmental sensing practices, for example, are clearly no longer "a classificatory and exclusively human project […] tied to particular kinds of human embodiment, engagement, and experience" (Gabrys 2019b, 724), but rather operate through an assembly of sensors, algorithms, data infrastructures, and the like, via which new, more-than-human ways of

knowing and acting are becoming possible (see Amoore 2019; Ascui et al. 2018; Gabrys 2019b; Machen and Nost 2021). To assert that these nonhuman objects have agency in these sensing practices is no longer a particularly novel claim, but it bears further explanation and situating amidst wider debates of concern to more-than-human geographers.

More-than-human geography emerged in the early 2000s as cultural geographers – drawing particularly on Actor-Network Theory, science studies, and vitalist philosophy – began foregrounding the agencies of nonhuman beings and material things in what were previously considered privileged human domains: culture, society, politics, and the economy (Barry 2013; Barua 2014; Braun and Whatmore 2010; Bennett 2010; Greenhough 2011; Haraway 2008; Hinchliffe et al. 2005; Whatmore 2006). To speak of these beings and things as having agency decouples agency from the criteria of intentionality, subjectivity, and free will (assumed the reserve of humans), and instead understands it in terms of capacities to affect and be affected – to make a difference (see Sayes 2014). Inspired by new materialist and posthumanist thought (see Alaimo 2010; Barad 2007; Braidotti 2015; J. Bennett 2010; Gandy and Jasper 2017; Wolfe 2010), more-than-human geographers resist anthropocentric research approaches in favour of a relational ontology and new forms of ethical orientation and politics that account for nonhuman agency, liveliness, and difference (see Barua 2014; Gerlach 2020). From strands of this research informed by science studies scholarship, we also gain an appreciation of scientific knowledge production as embodied, situated, and affective practices; involving tuning in and 'learning to be affected' by material worlds and nonhuman beings (see Hinchliffe et al. 2005; Latour 2004; J. Lorimer 2008).

A distinct subfield which shares many of these concerns, animal geographies, has sought to "bring the animals back in" to social theory (Wolch and Emel 1995, 632), redressing a silence about nonhuman animals in human geographical scholarship through engagements with the spatialities, politics, and reciprocal implications of human-animal relations across diverse contexts (see also Philo and Wilbert 2000b; Wolch and Emel 1998). Animals, this work suggests, matter too much as political and ethical subjects to 'leave to the biologists' (Hodgetts and Lorimer 2015, 286), emphasising the insufficiency of natural scientific epistemologies alone to account for the richness of nonhuman lives or to inform the kinds of ethical orientations and politics necessary for living in shared worlds (see also Buller 2014;

2016). This focus is reflected in conversant approaches across cultural anthropology, the environmental humanities, and related fields (e.g. van Dooren and Rose 2016; Kirksey and Helmreich 2010; Tsing 2012; see also Ingold 2013). However, a concern I share with others is that some of this work evidences an unwillingness or inability to account for geographically uneven distributions of power and responsibility, and the position I take here is one which recognises the lively agencies of nonhumans – such as technologies, animals, and oceanic volumes - without neglecting questions of power and political economy (e.g. Barua 2016; 2017; Collard and Dempsey 2013; Giraud 2019; Haraway 2008; Srinivasan 2016; Squire 2020).

2.4.2. Animals as sensors

In providing this brief overview of these literatures, my intention is, firstly, to affirm the claims made by existing scholarship on environmental sensing practices, which assert that these practices are increasingly more-than-human and involve forms of nonhuman agency. However, the manifestations of nonhuman agency we encounter in this existing scholarship are, by and large, distinctly technological. Geophysical forces are given some consideration in existing writing on ocean sensing, which often foregrounds the *recalcitrance* of the ocean; its messy, turbulent materialities are figured as agentive predominantly in terms of how they complicate and challenge sensing practices. However, beyond this focus on material recalcitrance, little work has substantively engaged with questions of how these practices enrol, and are configured by, the agencies of animals.

The import of such engagements becomes clear when we consider that environmental sensing increasingly takes place *with* animals, which are being enrolled as sensors in the contemporary sensing infrastructures through which environments like the ocean come to be known. An ontology of animals as "sensors of the environment" (Kays et al. 2015, 1222) diverges from a long history of enrolling the bodies and capacities of nonhuman animals in human projects of knowing by its reliance upon new digital sensing technologies and ecology as a 'Big Data science,' and its orientation towards knowing the turbulent ecologies of the Anthropocene (Farley et al. 2018; Kays, McShea, and Wikelski 2020; see also Gabrys 2016a). The use of animals as sensors has been the focus of much research in ecology

and (conservation) biology and has attracted modest attention from social scientists and humanities scholars (see Benson 2011; Forssman 2017; Johnson 2017). Gabrys (2016a, 83), for instance, identifies that "environmental sensor networks involve not just tracking and tracing animal activities but also new forms of computational and collaborative sensing, where […] sensing is undertaken with and through more-than-human technologies and organisms. In other words, it is not just the organisms that are sensed. *Organisms are transformed into sensors* that would also communicate registers of animal-based environmental sensation and inhabitation" (my emphasis). This ontological claim about animals has been understood as one that is also about environments as particular kinds of spaces. Johnson's (2017, 283) description of a "more-than-human sensorium for the Anthropocene" – where animals are configured as sensors and the planetary environment as "a solution space, a repository of ecological systems to be surveilled and potential solutions to be enacted" (p.287) – captures these two components together. Within this framing, animal-based sensing practices are frequently aligned with "technoscientific narratives that seek progression towards all-encompassing vision […and] narratives of the frontier as a site of creative energy and expansionism," as Natalie Forssman (2017, 14) points out in her ethnographic account of elephant seal 'oceanographers.'

Johnson highlights that, owing to the scientific, military, and corporate actors involved in developing new kinds of animal-based sensing, the creation of "conditions for extending the capacities of capitalist production" (2017, 287) and "securitizing the planet" (p.289) are important potential implications of these forms of sensing. However, overall, the specific forms of governance – if any – that these practices are associated with remain poorly articulated. Moreover, sensors or even oceanographers are useful framings but do not fully capture the dynamics that I explore in this research. Rather, I suggest in the following section, different understandings emerge from an awareness of animals not only as sensors, but also as sentinels.

2.5. From sensors to sentinels

In this section, I elaborate on my definition of environmental sentinels and how they build upon the ontology of animals as sensors discussed above. My proposition is that we can identify three different types of environmental sentinel at work in ecological science and environmental governance practices, and that, moreover, sentinels ought to be understood not only as discrete entities or devices, but also in terms of collectives and practices. In the following, and final, section, I think across the literatures, concepts, and approaches discussed thus far to specify 'sentinel geographies' as a promising field of geographical research to study emerging environmental governance practices that work with and through animals and ecologies, which is elaborated upon in the empirical chapters which follow.

2.5.1. Environmental sentinels

A sensor, at its most general, is defined as "a device that is used to record that something is present or that there are changes in something" (Cambridge English Dictionary 2023). Sentinels, while also performing this function, are additionally associated historically with acts of vigilance and warning. Whilst both sensor and sentinel derive from the Latin *sentire* – to perceive or feel – the sentinel is distinguished by its military origins where it names a vigilant solider or guard. Where sensors are devices which record information about the environment and changes within it, sentinels additionally communicate this information in the register of a warning or an incitement to action. Anthropologists Frédéric Keck and Andrew Lakoff (2013, n.p.) describe sentinel devices, for instance, as "living beings or technical devices that provide the first signs of an impending catastrophe," and have separately applied this concept specifically in the context of public health and pandemic preparedness. Lakoff (2015) contrasts sentinel devices with 'actuarial devices,' with reference to the divergent governance logics of risk management and vigilance. Risk management relies upon actuarial devices, which "assemble historical patterns of incidence in order to calculate the probable future, [whereas] vigilance requires sentinel devices that can provide early warning of an encroaching danger […and] stimulate action when decision is imperative but knowledge is incomplete" (p. 45).

An *environmental* sentinel, then, can be considered as a device for attuning to and responding to the threats of environments understood to be contaminated, turbulent, and

continuously materialising in indeterminate ways. They might either emerge in relation to a particular environmental event, for example when the death of fish or presence of certain microorganisms in a watercourse signals a pollution spill, or be more proactively designated owing to their known sensitivity to environmental perturbations and the infrastructures of scientific knowledge production that have been assembled around them, exemplified by multidecadal studies focused on particular organisms like birds and mussels. Environmental sentinels have been discussed by sociologists and anthropologists primarily in the context of local monitoring of environmental pollution (see Gramaglia and Mélard 2019; Gramaglia and Sampaio da Silva 2012; Gabrys 2018; Paredes 2022). However, the contexts and ways in which sentinel devices act – or incite action – can be extremely varied, and even those which appear superficially to be the same (in this case, seabirds) can function as sentinels in several different ways. Accordingly, there is a need to pluralise the concept of 'sentinel devices,' so that it is fit to describe the diversity of sentinels that we encounter in environmental, and particularly conservation, contexts. I do so through three distinctive but overlapping conceptualisations: *sentinel species, sentinels of sentiment,* and *operational sentinels.*

2.5.1.1. Sentinel species

Sentinel species are an example of what are commonly called 'focal' or 'surrogate' species (see Caro 2010; Zacharias and Roff 2001); species which are preferentially valued for their significance to environmental knowledge production, management, and conservation. Geographers have been particularly interested in two of these surrogate species: flagship species, mobilised to raise awareness and funds in support of specific environmental causes (see Barua 2014; Buckingham et al. 2013; Jepson and Barua 2015; J. Lorimer 2007), and keystone species associated with outsized ecological impact and the stimulation of desirable ecosystem functions (Barua 2011; Jørgensen 2015; J. Lorimer 2017; J. Lorimer and Driessen 2013). Although sentinel species is a well-established ecological concept, these species have received less attention from geographers, and direct researchers towards a different set of considerations. Their contemporary origins lie in the emerging late-20th century imperative to identify, via intermediary animal bodies, the effects on human health of exposure to toxic contaminants in the environment (Committee on Animals as Monitors of Environmental Hazards 1991; O'Brien et al. 1993; Reif 2011; van der Schalie et al. 1999). Their use has

broadened to refer to those species which signal changing environmental conditions and give *early warning* of those changes, their likely ecosystem effects, and, often, their human implications (see Caro 2010; Durant et al. 2009; González Carman et al. 2021; Zacharias and Roff 2001). [10]

From the scientific literature, we can further summarise that the concept of sentinel species evidences an ecological ontology through which these species become significant through their relations to other species, human and nonhuman, and their environment. Moreover, use of sentinel species is often motivated by an instrumental desire shaped by prevailing political economic contexts for cost-effective, often management-orientated, knowledge about environmental crises. With these insights in mind, this research seeks to address how and why specific species have *become* sentinels – which I suggest lies somewhere between the lively affordances of animals themselves and their own lived geographies (cf. Hodgetts and Lorimer 2015) and the political economic contexts within which the science of sentinels unfolds.

2.5.1.2. Sentinels of sentiment

As noted above, geographers and other social scientists have explored the characteristics of "nonhuman charisma" (J. Lorimer 2007) and how the affective capacities of charismatic species shape conservation practice, and conservation scientists have sought to identify, through quantitative methods, the most charismatic or most effective flagship species for conservation efforts (E. A. Macdonald et al. 2015; 2017; Verissimo, MacMillan, and Smith 2011). Most existing work in both the social and natural scientists has considered sentinel animals entirely separately from this work, and literatures on environmental sensing discussed above rarely consider affect, emotion, and feeling as important registers through which environmental change is sensed and made sense of. This is despite the fact that scientists and conservationists frequently strategically choose sentinel animals to

[10] To avoid confusion, it is worth clarifying that sentinel species are also often called environmental indicator, bioindicator, and biomonitor species, and vice versa, and whilst the scientific literature is divided on the significance of the differences between these concepts (e.g. O'Brien, Kaneene, and Poppenga 1993) I treat them together as sentinel species.

communicate early warnings of ecosystem change to publics and policy makers *affectively* as well as through appeals to scientific reason (see González Carman et al. 2021; Hazen et al. 2019; Moore 2008; see also Siddig et al. 2016). Albatrosses, for instance, have been framed to public audiences as "the symbol and the spirit of the status of the global marine system" (Croxall 1997, in Benson 2010). Indeed, where charisma and sentinels are considered together, it is often to place them in opposition. Lakoff (2016, 243), for instance, notes that efforts to protect the delta smelt, an endangered fish in the San Francisco Bay, "unlike movements to prevent the extinction of more charismatic fauna […], are not driven by an affective connection with the endangered animal. Rather […] the smelt's decline is symptomatic of a broader unfolding tragedy of ecosystem collapse." Ecologists Elliott Hazen and colleagues (2019, 2) call for more rigorous scientific criteria for the choice of sentinel species to remedy a situation whereby "the choice of a particular species is often based on the popularity of that species […] rather than broad scientific rationale."

Such accounts are too fast to summarily dismiss the significant role of charisma, affective connection, or popularity in the ways that many animals function as sentinels, something which I address in this research by developing the concept of 'sentinels of sentiment.' Sentiment here refers broadly to the affects, emotions, and feelings, individual and collective, that move people to care about nonhuman life, and 'sentinels of sentiment' is mobilised to capture the important sentiment-based dimensions to the signalling done by sentinel animals, operating in tandem, and sometimes in tension, with scientific, reason-based dimensions. This concept, further, allows me to make novel connections between work on sensing and conservation practices, and a diverse literature in geography and the social sciences which has come to understand affect, variously defined, as "crucial to any understanding of the operation and proliferation of different modalities of power and politics in the contemporary world" (Carter and McCormack 2006, 230; see also B. Anderson 2016; Massumi 2002; McCormack 2013; Thrift 2004).

2.5.1.3. Operational sentinels

Species are not always an appropriate unit of analysis for specifying animal sentinels as they are used by scientists and practitioners, however. Individual sentinel animals are also

enrolled in what Andrew Lockhart and colleagues (2023, 2) term 'operational ecologies': "emerging and experimental sites of environmental enclosure, control, intervention and exploitation, which involve the provision and management of bio-physical processes and resources vital for social and economic reproduction." These operational ecologies render animals into 'operational sentinels,' a concept which I deploy to distinguish them both from sentinel species and from the animals as sensors discussed above. These sentinels are, very directly, a tool of (often real-time) governance. For instance, unvaccinated sentinel chickens are used in poultry farms to signal the presence of avian influenza and trigger rapid biosecurity responses (Keck 2015); individual herbivores are tracked in conservation reserves and machine learning algorithms are used to identify movement patterns associated with the presence of wildlife poachers, which are then investigated by park security officers (de Knegt et al. 2021); and whales communicate their presence to marine management agencies via geographically distributed bioacoustics infrastructures and instigate spatial closures or speed restrictions on shipping traffic (Maxwell et al. 2015). These examples express what Barua (2021, 1481) refers to as a "'cyborg anatamo-politics' [which] is about modulating other-than-humans' mediatic capacities, reorienting animal bodies into technologies for dealing with shocks and turbulence," and a particular, technologically enabled, manifestation of a set of practices which leverage the 'naturalness of nature' for environmental governance purposes (Braun 2014, 60; see also Lorimer 2020; Wakefield and Braun 2019). The 'ocean sentinel' albatrosses equipped with radar detectors for sensing illegal fishing vessels and triggering naval control responses, discussed in Chapter Five, offer a particularly compelling example with which to explore the implications of such operational sentinels and the modes of governance they enable (see Weimerskirch et al. 2020). They also demonstrate that the locus of agency can be difficult to identify amongst operational sentinels; often, it is distributed across nonhuman bodies and technological devices which connect these bodies to larger digital, material infrastructures through which signals are conveyed.

2.5.2. Sentinel devices, collectives, and practices

Just as sensors are only one feature of broader sensing practices which are "articulating, animating, and operationalizing environmental collectives that are in the process of finding ways to live together in altered worlds" (Gabrys 2019b, 727; see also 2018), so too do we

need a richer conception of what sentinels are beyond a focus on the sentinel devices discussed above. Accordingly, in this research I also understand sentinels as distributed across collectives and performed through practices. Sentinels as collectives is a notion I borrow from Keck (2019, 256), who argues in his writing on sentinels in the context of virology, pandemic preparedness, and human-bird relations in China that "sentinels are not only technical devices sending warning signals but also collectives of humans and more-than-humans caring for their environment." These more-than-human collectives come into being within spaces configured around logics of preparedness and the anticipation of threats (see Blanchon et al. 2020; Keck 2015), and it is through these that a sentinel's signal emerges (as an effect of particular ecological and human-animal relations), becomes meaningful, and is acted upon. Practices as a way of thinking about sentinels draws from a more diverse set of resources, including the work of STS scholars interested in the enactment of objects and orderings through material semiotic practices (see Law 2002; Law and Lien 2012; Mol 2002), theories of how focal/surrogate species act and are enacted in practice (Jepson and Barua 2015; J. Lorimer 2020), and the work on sensing practices already discussed.

The sentinel as a set of practices distributed across more-than-human collectives has been cautiously celebrated as a recognition of nonhuman agencies and the collaborative production of more-than-human knowledge (Gramaglia and Sampaio da Silva 2012; Gramaglia 2013), and an acknowledgement of "interspecies transcorporeality," where vulnerabilities to environmental change are recognised as "violently distributed across species divides" and more-than-human solidarities become possible (Paredes 2022, 97; see also Alaimo 2010; Da Costa and Philip 2008). While I share a desire to affirm the ethical and political possibilities opened by environmental sentinels, this research follows recent engagements with the concepts of care (Cusworth 2023) and multispecies justice (Chao et al. 2022) in starting from the critical question *'cui bono?'* - who stands to gain from sentinel devices, practices, or collectives, and, conversely, who or what is silenced, harmed, or designated as background noise? What configurations are made imaginable and possible, and which not?

Through approaching sentinels thus, I come to understand them both as an indispensable part of certain contemporary environmental governance practices and – akin

to Michel Foucault's (1978) hysterical woman, masturbating child, perverse adult, and Malthusian couple as expressions of biopower and its operation, or Elizabeth Povinelli's (2016) desert, animist, and virus as expressions of 'geontopower' – as a figure through which these practices might be understood. Specifically, sentinel geographies as an approach which conceives of sentinels as more-than-human systems configured around organismal signalling of environmental threats or warnings points towards a recognition of distinctive forms of 'sentinel governance' which rely, at least in part, upon these systems. Others have described similar governance approaches as a "Sensing mode of governance" (Chandler 2018) and a self-aware 'Gaia 2.0' (Latour and Lenton 2018) whereby governance operates responsively to a continually unfolding world revealed through sensors and Big Data. As the following chapters, particularly Chapter Five, demonstrate, sentinel governance differs from these conceptualisations of governance through an uneasy and unresolved tension between top-down forms of governance entailing totalising monitoring and surveillance *of* environments, and a more emergent, responsive way of governing in response to signals emergent *from* environments and nonhuman bodies and modes of experiencing. Sentinel governance is also put forward as a speculative as much as descriptive notion, in so far as the thesis proposes at several points where modes of governance involving sentinels may be developed, altered, and improved.

2.6. Conclusion: sentinel geographies

Sentinel geographies is proposed as a novel field of geographical inquiry incorporating the components of the conceptual framework offered in this chapter. This involves an attentiveness to environments and the contexts of motivation shaping the ways in which they come to be apprehended and governed. It entails a recognition of the more-than-human constitution of environmental sensing and governance practices, which increasingly take place with and through varied digital technologies as well as nonhuman animals and ecologies, and are associated with multiple possible environmental outcomes and politics. Finally, it approaches sentinels through a focus on devices, collectives, and practices. In the following chapter, I turn to the methodological orientations and methods through which this approach is developed in this thesis and the research aims and questions outlined in the introduction are addressed.

Chapter Three

Methodology and methods

3.1. Introduction

My aim in this chapter is to outline the methodological approach through which this research was performed. I begin by reiterating the research questions this thesis seeks to address and the process by and position from which I arrived at them, before moving to a discussion of the geographies of my fieldwork. I then describe the varied techniques through which materials were generated (following Whatmore 2003)[11] in this research, which included document analysis, semi-structured interviews, participant observation at events and dockside with fisheries observers, and through different modes of attuning digitally and corporeally to seabirds and marine ecologies. Discussions of ethical research practice are layered into this description. Finally, I detail the iterative process of analysing and writing these materials and offer a reflection on the 'odds and ends' and 'paths not taken' in this research.

3.2. Which came first, the seabird or the sentinel?

As a reminder from the Introduction, this thesis seeks to answer the following research questions: *i) how and why have seabird become sentinels; ii) how are seabird sentinels used to govern ocean space and with what consequences; iii) how do sentiments shape how seabirds act as sentinels; and iv) how are the promises of digital ocean governance complicated in practice and with what implications for seabirds and marine ecologies?* These questions have emerged and changed as this research has progressed. I started from an interest in understanding how and why animals become sentinels (the sentinel came first) and what their roles in contemporary environmental knowledge production and governance are, one informed by my existing grounding in more-than-human research – which shaped the kinds of concepts I brought to the research. As I described in the Introduction, seabirds offered an exemplary (if quite different from other animal sentinels discussed in existing literature) case through which to explore these roles, and I also outlined how and why albatrosses became a more specific concern, and why much of this research focuses on a

[11] Generating materials is used to push back against the extractive logic implicit in 'data collection' and its assumption that data is simply free-floating and 'out there' in the world ready to be gathered to fulfil a research purpose.

specific conservation problem – seabird bycatch in commercial fisheries. In Chapter Two, I justified my interest in the ocean as a key operational space for sentinels, where these are one of the varied more-than-human ways in which marine environments are sensed and governed. I also arrived at this focus from a pre-existing interest in ocean governance from my master's research on coral reef governance. Slightly modified, then, my initial interest is captured in the first two research questions.

The third and fourth research questions emerged later, from my empirical materials. Making sense of seabirds' roles as sentinels came to require an engagement with sentiment (the actors' categories here were flagship species, charisma, popularity, and/or public appeal), as I discuss in Chapter Six. Similarly, whilst I came to the research with an interest in the digital ways of knowing and governing that animal sentinels are entangled with, the focus on how these are complicated in practice developed from the repeated recurrence of this theme in interviews, participant observation, and document analysis (see Chapter Seven). My approach and questions were thus partly developed beforehand – I came to the research with a set of ideas and concepts to 'test' and understand further – and partly emerged through the research process and were derived from the empirical materials.

These questions serve a twofold purpose, to guide my exploration of the specificities of the cases I discuss and to identify and work through meaningful commonalities between these cases and wider phenomena that they are, at least in part, examples of. The conceptualisation of sentinel geographies I developed in the previous chapter, for example, rests on a claim that my empirical materials allow me to make a wider set of observations about environmental sentinels; that they are not defined solely by their singularity. Such case study approaches have, for these reasons and others, received mixed appraisal from geographers and other qualitative social scientists (see Castree 2005; Flyvbjerg 2006; Tight 2010). I try, here, to navigate between the nomothetic (there is an ontological regularity across cases in different contexts) and the idiographic (context is irreducibly constitutive) through a comparative approach. These comparisons are both made *within* my empirical materials – for instance, between different instances where seabirds are sentinels – and at their margins – between different instances of animals used as sentinels, for example, determined through document analysis and some interviews with a wider ensemble of

sentinel scientists. Clearly, through more comparisons the differences between 'cases' of environmental sentinels (or fisheries monitoring, as in Chapters Five and Seven) might multiply such that these become more significant than their commonalities. My claims to generalisability reflect this and avoid what Eve Kosofsky Sedgwick (1997) terms a 'paranoid' mode of critical theoretical inquiry whose orientation is towards 'strong' – generalisable, powerfully explanatory – theory. The approach is more affirmative, open to the difference and surprise that emerges from particular empirical situations and forging comparisons between them (see McCormack 2012; Woodyer and Geoghegan 2012).

3.3. Geographies of the field

> "Rather than wheezing in the archives, the historian grows bleary-eyed and finger-sore from clicking through digitized manuscripts; the pajama-clad anthropologist stays up late observing online videos and participating in chat rooms; the oceanographer is swept up in wave after wave of satellite images; the hydrologist drowns in a flood of data from automated stream gauges" (Benson 2016b, 1–2)

The comparisons described above become possible through the multi-sited fieldwork I have pursued in this research. Fieldwork holds a privileged place in geographical research; as Anna Guasco (2022, 468) observes, it is "the presumptive rite of passage in geography" and remains strongly tied to the supposed authenticity and authority that follows from 'going there.' The colonial and othering mindset implicated in constructing and exotifying the field as 'out there,' detached from the researcher is much discussed (see Katz 1994; Liboiron 2021; Massey 2003; Rose 1997). There is a danger to wedding fieldwork too closely with a mode of embodied experience in (often remote) places; fieldwork can be done, and done well, without going somewhere geographically distant from 'here.' Indeed the field, following scholars cited above, is best understood as a relationally constituted spatiality which comes into being through research, and not a distinctive geographical location. Why not just call this 'research'? Following from Etienne Benson's description above, much contemporary research across the natural and social sciences and humanities takes place in a 'virtual field'; in sites with specific spatialities, materialities, and associations with specific social norms and practices in ways that make them meaningfully *field* sites – they are sites where things happen and that one can go to, navigate, and interact with "behind [or beyond] the screen"

(see Kozinets 2002, 61) through a variety of "less proximate sensing practices" associated with digital fieldwork (Gabrys 2021, 4). Distinguishing between fieldwork and an "ethic of not going there" (Guasco 2022) reproduces a dubious distinction between offline and online, 'real' and 'virtual', which is the subject of recent critique (see Turnbull et al. 2022). Digital or remote fieldwork can thus alternatively be thought of as taking place in and across sites that are "more-than-real" (McLean 2020).

My fieldwork thus engages calls for multi-sited research to understand conservation practices (Brockington and Duffy 2010) and fisheries management (Lien 2015), even as much of it took place remotely. This follows a range of studies which have employed similar approaches for studying environmental knowledge production and governance (for some diverse examples, see Asdal and Hobæk 2016; Drakopulos et al. 2022; Gabrys 2021; Prebble, McLean, and Houston 2021). The multi-sited approach developed in this research was not entirely online, though, and I am not seeking to devalue field visits *per se* as a valuable and important part of research. Some things were difficult to witness or encounter online and, as I describe in following sections, there were several instances where I travelled to particular sites when this was possible and pertinent to the aims of this research: to watch seabirds, go to an in-person-only event, and engage with the practical aspects of deploying digital technologies for fisheries monitoring, for instance.

3.3.1. Research during COVID-19

This hybrid approach was partly born of necessity. Like many research projects which commenced between 2018 and 2021, the approach I have pursued in this thesis and its composition as a whole are inflected by the COVID-19 pandemic and its various fallouts. There has been much reflection on the general methodological implications of the pandemic on qualitative social research and its longer-term implications, which I won't expand on in detail. It can be summarised simplistically as researchers engaging with established digital qualitative research methods and developing new ones (see Howlett 2021; Keen et al. 2022; Kim et al. 2021; Lupton 2021). In this research, too, fieldwork plans and planning were disrupted, cancelled, and new approaches were developed. What *is* worth briefly expanding on in relation to the pandemic is that although it posed challenges to doing research that

were in many ways new and exceptional, pandemic or not research rarely goes entirely according to plan. Much has been said in qualitative social scholarship about the drawbacks of a linear model of research from literature review through to write up, as neither a 'good' way of doing research nor an accurate description of actually existing research practices (see Law 2004; Marshall and Rossman 1989). Research is messy, non-linear, and diverges from the formalities of off-the-shelf methods in all manner of ways. These diversions and surprises are an important feature of good research (see Crang and Cook 2007), and some aspirations are inevitably always abandoned or rehashed along the way. Recognising this messiness, and moments of failure, forms an important part of my practice of honesty and reflexivity and acknowledging subjectivity in research practice (see Harrowell et al. 2018; Rose 1997).

In practical terms, the context in which this research was undertaken has meant that my approach runs somewhat counter to an ethnographic focus on practices which forms a significant focus of the kinds of more-than-human approaches I situated this project in relation to in the previous chapter. This focus entails foregrounding what people *do* rather than what they say they do (see Thrift 1996), and how things are enacted through practices as well as discursively (a material semiotic approach; see Law and Lien 2012). The opportunities to engage such an approach were *limited*, but there were some. In keeping with the conceptual framework developed in the previous chapter and the broader aims of the thesis, I adopt a 'more-than-representational' (see H. Lorimer 2005) sensibility, which expands beyond the discursive as its principal frame of reference, to the document analysis, interviewing, participant observation, and modes of attuning to seabirds online and corporeally that form my methods. There is precedent to doing so, and existing work shows that a principal focus on 'talk and text' (see Whatmore 2003) does not preclude such a sensibility. I describe how this was applied in practice in the following sections. A final practical observation here concerns the temporality of this research. The first iteration of the research design following the onset of pandemic restrictions entailed two phases: the first online and the second in person once travel restrictions and institutional restrictions were lifted. However, as I built momentum in the first phase and developed new approaches, questions, and a geographically widespread network of interlocutors rather than a focus on one or a few bounded sites, I decided, having drafted two empirical chapters from the first phase, to continue the second phase mostly online. The research thus took place through

two more-or-less distinct phases of generating materials, analysing, and writing, sometimes together and sometimes separately.

3.4. Methods

3.4.1. Document analysis

Documents form a key part of my research materials. My approach to analysing documents is particularly informed by the 'practice-oriented document analysis' method developed by STS scholars Kristin Asdal and Hilde Reinertsen (2021). This approach understands documents as sites, which one might enter into as a kind of fieldwork to understand particular issues. Indeed, a key intervention of this method is to consider document analysis as a methodologically rich stand-alone approach rather than a supplement to other qualitative methods. Moreover, following a material semiotic approach, it treats documents as both texts amenable to forms of textual analysis, and as material objects whose production requires varied kinds of work and which do work in the world through the assemblages they are embedded within.[12] The method, which approaches documents as tools of knowledge for making issues visible and tools of governing which make it possible to act upon them, entails attending to how environmental phenomena and problems are brought into being and made governable through documents (Asdal and Reinertsen 2021, 5; see also Asdal 2015; Asdal and Hobæk 2016).

It may be helpful to illustrate this through an example. Seabird bycatch, the conservation issue which forms a central concern of this thesis, is both a phenomenon 'out there,' literally the horrifying, material stuff of birds becoming entangled in fishing equipment and dying, and something defined, debated, and made actionable by way of documents. These include those mapping seabird distributions (e.g. Clay et al. 2019); defining global political responsibilities for seabird conservation (e.g. Beal et al. 2021); establishing guidelines

[12] Asdal and Reinertsen (2021) detail this method as having six components: document sites, document tools, document work, document texts, document issues, and document movements. Because of the breadth and quantity of documents I treat in this research, I have not applied these all together, but find the six-part framework to be a useful toolkit for orienting my approach to these materials.

for bycatch mitigation (e.g. Agreement on the Conservation of Albatrosses and Petrels 2021); or arguing that guidelines have had minimal impact on practice (e.g. Gilman 2011). Lauren Drakopulos (2020, 100) has argued – and I agree – that bycatch is therefore something that is "enacted through the material-discursive practices of science and policy," requiring analysis of scientific and policy documents to understand this enactment. The same is true of the enactment of seabirds as sentinels beyond this specific context; it happens in and through documents and these therefore become important fieldwork sites in their own right. This approach is followed most faithfully in Chapter Four, where documents form the main empirical materials. The research question here, '*how and why have seabirds become sentinels?*', was best addressed through analysing decades of scientific papers, reports, and policy documents, alongside interviews with mid- to late-career seabird scientists from different backgrounds with extensive experience and knowledge of the history of their discipline (see following section).

Beyond the examples above, the 'field' of documents involved here is multi-sited and expansive, but bounded mostly within the following: published scientific research in the fields of seabird ecology, movement ecology, conservation biology, fisheries science and management; policy documents and guidelines produced by national governments, intergovernmental organisations, and environmental NGOs relating to fisheries management and marine and seabird conservation; and news articles, blogs, and popular writing relating to these themes. Relevant documents within these categories were systematically identified through Web of Science and Google Scholar key word searches, using literature mapping software (Connected Papers), Google searches, databases,[13] and through interviews and email exchanges with interlocutors. Documents were all downloaded and categorised into different folders by focus, sub-focus, themes, and type (e.g. seabird bycatch → albatross bycatch → bycatch mitigation measures → scientific articles). The aim was to explore topics, issues, and debates from multiple angles, map out perspectives and key themes, and

[13] Such as the Bycatch Management Information System (see https://www.bmis-bycatch.org/references), the data portal of the Agreement on the Conservation of Albatrosses and Petrels (see https://data.acap.aq/), and the EM4Fish electronic monitoring in fisheries online library (see https://em4.fish/browse-our-library/), to give some examples (all last accessed: 02.09.23)

gradually I moved towards selecting important illustrative examples (placed into 'key documents' folders for each focus area).

There are potential drawbacks to such an approach – some might highlight incompleteness and the entry of selection bias - but again, the approach here is not about seeking a generalisable, singular 'truth.' It is more akin to what sociologist Yiannis Gabriel (2018) calls 'beachcombing' or others 'collage' (see Crang 2003): reflexively working through materials to identify promising narratives and points of interest and placing those into potentially-unsettling relation with concepts and other materials. This is particularly evidenced in Chapter Six, where the cases used to illustrate the concept of 'sentinels of sentiment' were based on a thorough review of projects and initiatives using albatrosses in different ways to convey conservationist and environmentalist messages, entailing sorting through websites, articles, online archives (e.g. BBC news archives), documentaries, and relevant social media pages and categorising the materials by type, tone, message, and defined or implied audience. The final cases selected are broadly representative of three prominent logics according to which albatrosses are used as sentinels of sentiment, based on this review, but they were also deliberately chosen as particularly compelling examples with a broad circulation among interested publics.

3.4.2. Interviews

Document analysis was augmented through targeted, semi-structured interviews. In total, interviews were carried out with 27 participants across 29 interviews typically lasting between one and two hours.[14] These took place over two distinct stages, reflecting the research design developed in the context of the pandemic: the first between summer 2020 and summer 2021 and the second between winter 2022 and spring 2023. Their focus was relatively distinct; the first involved interviews with marine ecologists from universities and government research agencies working with animals as environmental sentinels across different contexts and those working specifically with albatrosses, as well as with conservation practitioners from NGOs who focused on seabird bycatch in fisheries.

[14] Two of these were repeat interviews to clarify particular concepts and themes and to continue conversations cut short by participants' other commitments..

Participants were selected based on general subject expertise (their recurrence in the literature), their involvement with specific projects of interest (like the Ocean Sentinel project described in Chapter Five), and to gain differing perspectives by career stage, role, form of expertise (e.g. data technicians as well as field ecologists), and context (national and institutional). The second phase focused on actors involved with electronic monitoring (EM) in fisheries, including policy and technical experts at NGOs and government agencies, conservation practitioners developing seabird-specific guidelines for EM, and technicians and EM programme managers from marine technology companies. Participants were deliberately chosen to reflect different epistemic communities and forms of engagement (broadly: research, practice, policy, and industry). These two phases map roughly onto the themes of i) Chapters Four, Five, and Six, and ii) Chapter Seven. Thematic overlaps mean this is not a firm distinction; drafts and ideas developed from the first stage were revisited after the second.

Table 1 - Interview Details

CATEGORY	DETAILS
NUMBER OF PARTICIPANTS	27 (2 repeats).
LOCATION	Online (n=27) and in person (n=2).
FIELDS REPRESENTED	Seabird and marine ecology; marine/fisheries policy; marine conservation; engineering and technical disciplines (university, private, non-governmental, and governmental).
PARTICIPANT DETAILS	Participants who identify as men (n=13) and women (n=14); various career stages and roles; broad geographical representation as relevant to fields of interest (Australia, Brazil, France, Aotearoa New Zealand, Norway, South Africa, UK, USA).
SAMPLING STRATEGY	Purposive and through contacts/snowballing.
SATURATION CRITERIA	Interviewing was discontinued when an adequate depth and breadth of information and saturation in generated codes was reached, and no new coding themes or contradictory information appeared (Bowen 2008; Glaser and Strauss 1967; Guest et al. 2006). New examples around a theme might have continued to emerge, as well as different themes or directions beyond the broad remit of this research, but significant repetition was reached relating to the themes of interest and by triangulation across methods.

RECORDING, TRANSCRIPTION, STORAGE	Interviews were recorded on my mobile phone and transcribed and stored on my personal encrypted computer.
ANALYSIS	Interview transcripts were annotated and coded using NVivo qualitative data analysis software (Version 12) and parallel paper notes and maps.
INFORMED CONSENT	All participants were sent consent forms and participant information sheets detailing the purposes of the research, participants' roles, and how materials would be used. Participants were made aware that they could opt out of the research process at any time. Most returned signed consent forms while some participants expressed consent via email.

Participants were selected through purposive sampling and via the contacts I developed as the research unfolded. Bar a few unreturned emails, I was able to speak with everyone I identified as important interlocutors. The communities of practitioners of interest were relatively small and, based on reviews of academic and grey literatures in the fields of interest, interviewees represented an adequate breadth of possible participants. Efforts were made to ensure diverse representation by gender, career stage/position, and geographical location/national context as appropriate to the research. Interview participants could all reasonably be described as experts, but the approach taken here differs from a standard blueprint for expert interviewing which Merje Kuus (2013, 52) describes as "one-off interactions to obtain authoritative assessments on substantive issues." My interest was not in authoritative assessments but learning about the situated knowledges of my research participants and producing partial understandings together. Generally, interviews took place alongside the document analysis approach described above; I would read extensively, make notes, identify potential participants, devise questions, conduct interviews, and proceed cyclically through this process. The rationale for these interviews was not to find out if how things were presented in these texts was how they *really* were, or if really, they were different, but rather to identify different partial perspectives on issues (those described above), to set them into the contexts of research and conservation practice and gain insight into what was left out of or unsaid in document materials. As I outline later in this chapter, participant observation at events added to this an awareness of what was left out or the particular way things were presented in these interview conversations.

While I note the processes for receiving informed consent from participants in the table above, many geographers have rightly highlighted the limitations of a procedural model of research ethics which begins and ends in the process of seeking and receiving informed consent from research participants. For Nigel Thrift (2003, 107), and others, the 'audit culture' expressed via the Research Ethics Committee is somewhat at odds with an approach to practising ethics premised on "cultivating the faculty of *good judgement* in the course of encounters" (see also Greenhough 2007). For example, amongst the researchers and practitioners engaged in seabird conservation, most people are familiar to one another, and I would often be asked who I'd already spoken with. Good judgement involved developing a sense for when it was and was not appropriate in interviews to reference conversations I had had with other members of this epistemic community and learning to negotiate sometimes prying questions about these conversations (e.g. 'well, what did X say about that?').

What was also sometimes difficult to navigate, which others have noted about expert interviewing (see Kuus 2013), was that although I came to interviews with my own questions, they would often unfold with as many asked back at me – about my interest, approach, and findings. Some would quickly partition my concerns as 'philosophical' while others – particularly scientific researchers or those with a research background - were knowledgeable about social scientific concepts and would joke about the way I was asking questions and anticipate what I was trying to get at – actively framing and directing the conversation in ways that took some adjusting to. The result was not, then, a set of answers to a set of questions but a mutually negotiated and constructed conversation where I often had to account for myself and my positions as much as I was asking my interlocutors to. Several participants also requested to know more about the context in which they were being quoted in the text or to see chapter drafts, and with others I have re-confirmed consent for use of shared materials such as screenshots from video calls. Practising ethical research therefore entailed an ongoing process of accountability and was not a one-off finality bounded by the signing of consent forms. In the following empirical chapters, quotes from interviews are

attributed to interviewees via pseudonyms, date of the interview, and their role within the organisation they work with.[15]

Most interviews were conducted online via video call. Traditionally, online or remote interviews have been approached by qualitative researchers as impoverished versions of face-to-face interactions, where the generation of rapport and dialogue can be more difficult, participant fatigue more commonplace, and the possibilities for meaningful interaction more constrained. These are observations made particularly for telephone interviews (see Irvine, Drew, and Sainsbury 2012), and some are challenged by developments in video calling software and many peoples' growing familiarity with using it for personal and professional interactions. Indeed, benefits to online video interviews include widened geographical scope, the capacity for interviewees to fit interviews into their schedules, and visual cues similar to if not a perfect replica of face-to-face interactions (see Deakin and Wakefield 2013; Keen et al. 2022). Although this raises important concerns about uneven access to the necessary technologies, internet connections, and familiarities with software – intersecting issues of a "digital divide" (see Brock 2014; Kim et al. 2021) – these were not significant here given the socioeconomic backgrounds and geographical situations of my interlocutors.

As Sam Keen and colleagues (2022) observe, video calling presents opportunities not simply for supplementing traditional interviewing methods but also for methodological innovation. Many of the day-to-day practices of disciplines that have been historically conceived as field sciences increasingly take place online, interacting with data at a screen, for example. To gain an appreciation for these desk/screen-based research practices in the absence of possibilities to observe them in person, I repurposed elements of what have been called 'walking interviews' (Evans and Jones 2011) or the 'go along method,' for use in digital spaces. Margarethe Kusenbach (2016, 154) describes the 'go along' as a hybrid between interviewing and participant observation which entails "a more active stance towards capturing […] informants' actions and interpretations" (than extended ethnographic research) by following informants on their usual 'outings' and asking questions, listening, and observing along the way. Using the screensharing function in Zoom and Teams, I was able to

[15] Organisations are named unless they are too small to reasonably preserve anonymity, in which case the type of organisation is described.

go along with my interlocutors as they conducted tasks like data analysis and visualisation and, asking questions, to situate these in relation to their wider their work.

Much as walking interviews are described as being "profoundly influenced by the landscape in which they take place, emphasising the importance of environmental features in shaping discussions" (Evans and Jones 2011, 849), here, shared access to the digital spaces and applications being used enriched and shaped discussions. For instance, Ellen, a technical officer with BirdLife International, carefully walked me through the process of analysing and cartographically representing seabird tracking data using a software package in R (see Figure 3).[16] In Chapter Seven, I describe a similar go along with technicians from a fisheries monitoring company as they conducted analysis of electronic monitoring video data from fishing vessels using the software 'FishVue Interpret Pro.'[17] I'll note here that there was something intensely affective and disturbing about seeing dead seabirds appear on screen in the video footage being analysed, in a way I was not prepared for after the dulling effect of reading endless papers about seabird bycatch.

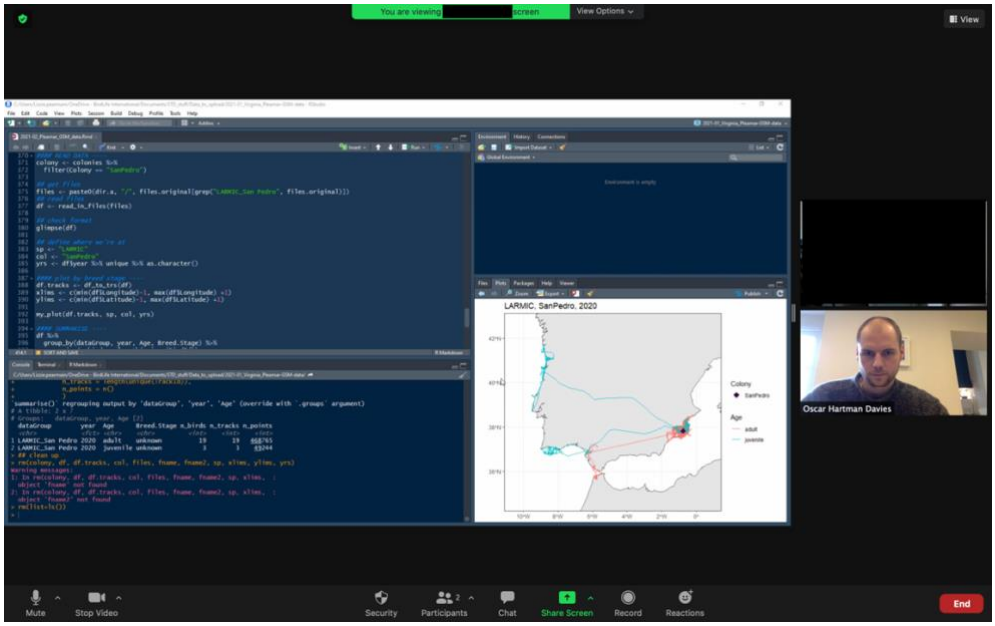

Figure 3 - An example of a data analysis 'go along'. Author's image.

[16] R is a software environment for statistical computing and graphics. See https://www.r-project.org/ (last accessed 12.09.23)

[17] FishVue Interpret Pro is a commonly used electronic monitoring data analysis software developed by Archipelago Marine Research. See https://www.archipelago.ca/products/fishvue-interpret (last accessed: 20.06.23)

This approach was also helpful for gaining an (admittedly curated) understanding of scientific practices beyond the desk. For example, Georgia, a seabird ecologist, described to me in rich detail the process of generating albatross tracking data, from identifying the bird a GPS logger would be attached to, capturing the bird and attaching the device, waiting for the bird's return from its foraging trip to its nest, to eventually re-capturing the bird, retrieving the logger, and uploading the data. As Georgia explained these different steps, she shared maps, images, and excel spreadsheets on screen, and this also created moments to reflect on particular fieldwork events. For instance, during a particularly long foraging trip by one albatross, which was visualised with a GPS track on screen, Georgia described beginning to feel anxious that something had happened to the bird at sea, then increasingly certain that it had, and, finally, experiencing joy and relief following the bird's return.

3.4.3. Participant observation

Document analysis and interviews were supplemented by attending events pertaining to the fields of interest – seabird conservation and (digital transformations in) fisheries governance. Conferences, meetings, and other events are important sites where issues relating to conservation and environmental governance are articulated, defined, and debated. Despite Campbell and Brosius (2010, 247) noting that, "there has been a surprising lack of ethnographic attention to 'the meeting' as a field site," in recent years, participant observation at events like international environmental conferences (sometimes termed 'event ethnography') has become common practice in qualitative studies of environmental governance. Such events, marine governance scholars Alice Vadrot and colleagues (2021, 170) suggest, provide "the opportunity to study actors, power constellations, conflicts, influence, and contestation in practice and 'on-site'." My use of event ethnography – or, better, event participant observation (following Ingold 2014) – involved attending conferences, seminars, and workshops relating to seabird science and conservation and the use of digital technologies in fisheries governance (see Table 2). Events were mostly attended online, and one in person.

Table 2 - Events attended during fieldwork

DATE	EVENT	DESCRIPTION
09.2020 - 04.2021	Seafood and Fisheries Emerging Technologies (SAFET) conference online webinar series (online)	Six sessions covering topics including advances in fisheries electronic monitoring, technologies for small-scale fisheries, deriving value from ocean data, and technologies for fisheries monitoring, control, and surveillance
10.2020	EM4Fish Fishermen's Roundtable on Electronic Monitoring (online)	Seminar on fishers' experiences engaging with on-board electronic monitoring technologies in North America
10.2021	3rd World Seabird Conference (online)	5-day conference with sessions on seabird tracking, conservation, seabird bycatch in commercial fisheries, and monitoring, demography, and surveys
11.2021	South Georgia Association Seminar – Why Japan is important in the fight to save South Georgia albatross (online)	Seminar on efforts to engage Japanese publics and policy makers in seabird bycatch mitigation, presented by conservationists from BirdLife International
08.2022	15th International Seabird Group Conference (in person and online, attended online)	4-day conference with sessions on biologging, population monitoring, movement and behaviour, and fisheries
03.2023	Indian Ocean Tuna Commission Working Group on Electronic Monitoring Standards meeting (online)	A two-day regional fisheries management organisation (RFMO) meeting on implementing electronic monitoring standards for Indian Ocean tuna fisheries
03.2023	Seafish Fisheries Management and Innovation Group meeting – Fisheries data and remote electronic monitoring (in person)	Day-long workshop in London on electronic monitoring in fisheries with presentations from fishers, fishing industry representatives, researchers, tech companies, and UK government representatives (DEFRA, CEFAS)

Events were chosen to represent a diversity of actors, topics, and sizes, and emerged as appropriate ones to attend by triangulating between interview conversations, researcher

and research group social media accounts, industry newsletters and so on. Some were selected because they were 'field-configuring events' (the most prominent meetings for practitioners in a particular field; see Schüßler, Grabher, and Müller-Seitz 2015), while others were smaller with a more specific focus. Attending smaller events allowed me to address gaps in my empirical materials or to understand a particular topic in further depth, such as the role of Japan in albatross conservation or fishers' perspectives on monitoring technologies. Together, these events allowed me to identify new potential interview participants, 'cross-check' themes emerging from interviews and document analysis, and to identify new themes or aspects of particular debates that I hadn't picked up on through other methods.

The method itself entailed scrutinising event programmes for key themes, attending sessions, making notes, asking questions of presenters, and engaging in conversations in the chat (online), observing interpersonal dynamics and searching for 'gaps' - topics and themes left unaddressed – as well as comparing observations across events and with other research materials. Generative moments emerged particularly in discussions between participants, where the clear, rehearsed logics of presentations (or, indeed, the documents described earlier) were disrupted or set into context, illuminating areas of consensus as well as contention and disagreement. For instance, at a major seabird conference, some participants spoke out against the attention and funding albatross conservation received which they saw as working against their aims to conserve other seabird species. A heated discussion broke out at one fisheries monitoring conference over the slow pace of adoption of electronic monitoring technologies, exposing tensions between governmental marine management agencies, fishers and fishing industry representatives, and fisheries monitoring companies. A further benefit of this approach was the ability to observe how the power dynamics and informal, tacit agreements shaping what could be said and how at events contrasted with how interview participants – also often present at these meetings – described particular issues. Sometimes, critical perspectives offered in interviews were more disciplined and muted at events, other times the opposite was true.

Event participant observation presents some challenges to individual researchers, particularly when events are large and involve multiple parallel sessions. Unlike the modes of

"collaborative event ethnography" developed by interdisciplinary teams for large environmental conferences (see Campbell and Brosius 2010), I could not multiply to attend different sessions simultaneously. However, recordings were made available online for a period or permanently for most events, allowing me in a sense to be in several places at once. The level of immersion was of course then reduced – I could only ask questions and engage with other participants in one session at a time. Of the challenges events pose, however, ethical issues are rarely explicitly considered. Events pose unique ethical conundrums relating to their sometimes-indeterminate position between public and private space. For instance, they can be entirely open to the public, open but involve signing up to attend, or by invite or application only. These different contexts will inform participants' expectations around privacy and what constitutes informed consent, and, as researchers have noted about online spaces, participants may still have strong expectations around privacy even when operating in ostensibly public spaces (see Buck and Ralston 2021). I have tried to avoid the problem of 'lurking' – "when researchers covertly collect data without participating or stating their aims" (Grinyer 2007, 2) – by specifying my motivations for attending to event organisers through the event sign-up process. Recognising that organisers and attendees may have different expectations of privacy, I used the chat function available in online events to introduce myself and my research motivations to event attendees and similarly clarified to people I spoke with at the in-person event that I was there conducting participant observation for my doctoral research and explained its focus. I did not record presentations/conversations at events and do not quote from these in the thesis, unless recordings of events are publicly available online.

There were a few further exceptions to my primarily online research. While analysing documents and conducting interviews relating to electronic monitoring technologies in fisheries, it became evident that I would benefit from seeing how these technologies work in practice. How were these technologies installed onto boats; how were they maintained; how were data hard drives collected and replaced? How did these practices affect their functioning? What happens when these technologies break? These were questions I posed in interviews, but I felt it was necessary to supplement the answers I received through observations of practice and the materiality of these technologies and the vessels where they are deployed. Kindly, Kevin, a technical officer from a fisheries monitoring company

conducting a seabird bycatch monitoring trial in the UK, agreed to bring me along to observe and ask questions as he checked, maintained, and replaced equipment installed on gillnet fishing vessels on the south coast of England. We also met and spoke with fishers participating in the trial. I expand on this encounter further in Chapter Seven.

3.4.4. Beyond text and talk

My research methods mainly follow the familiar 'talk and text'-based repertoire of humanist methods that Whatmore (2006, 606) identifies. More-than-human and animal geographers, along with others, have noted the limitations of such methods for engaging with nonhuman lifeworlds, which skew studies of human-nonhuman relations towards the human (Buller 2015; Hodgetts and Lorimer 2015). Tim Hodgetts and Jamie Lorimer (2015, 287), for example, observe that "the bias towards ethnographic methodologies involving participant observation of humans in their interactions with nonhumans; interviews with human subjects about their experiences with nonhumans; discourse analysis of human representations and mobilizations of nonhumans; and the like – leads to the retention of a bias towards human sensings of nonhumans." This is, avowedly, an account of human sensings of (and also with) nonhumans. The bias I retain here towards human-focused methods is appropriate to the research aims and questions of this thesis, but it does limit some of the things I might say about the "beastly places" of seabirds' geographies (Philo and Wilbert 2000a). Nevertheless, I have supplemented the approaches discussed above with some modest methodological experimentation and attunement intended to bring seabirds and marine ecologies into this research in more lively ways.

3.4.5. Attuning to seabirds

3.4.5.1. In texts and on the screen

More-than-human geographers have developed methodologies for "witnessing and evoking human-nonhuman interactions" as these occur within images and textual representations (J. Lorimer 2010, 237; see Dwyer and Davies 2009; Patchett 2017; Yusoff 2007). Such 'lively' readings of visual and textual materials seek to draw out the embodiment and affect at play in these materials, to animate them in novel ways. Rachel Squire (2020), for instance, seeks

to amplify the presences of animals in her readings of archival materials pertaining to the US Navy's Sealab projects, to account for the active role of animals in how these projects pursued human habitation of the seafloor. As I noted above, a complementary approach has been pursued by STS scholars through the practice-oriented document analysis method. Working across these approaches, I have sought to read for presences of lively, material things and phenomena – like seabirds, seabird bycatch, and marine ecologies – within documents.

There are many other ways in which seabirds circulate and can be encountered online besides documents. Indeed, their enactment as sentinels is dependent upon tracking and multi-year monitoring datasets which are stored and accessed in online databases,[18] and visual media including nature documentaries, YouTube clips, Instagram posts, and webcam livestreams through which their plights and those of their marine environments are communicated (see Chapter Six). A large literature details the varied digital ethnographic approaches through which such sites can be accessed and researched; here, I have drawn inspiration from, amongst others, Jonathon Turnbull and colleagues (2020) approach to engaging "quarantine encounters with digital animals," Jennifer Gabrys' (2021) digital multi-sited forest fieldwork, and Ben Light and colleagues' (2018) 'walkthrough method' for the study of digital applications. Through this latter method, it was possible to engage applications and databases where seabirds are digitally present as field sites which I could systematically navigate and engage with to understand their user communities and functions. As I described above in reference to digital go-along interviews, these sites can also be navigated *together* with these user communities through screen-sharing, linking them to other field sites and practices. Through these approaches, the various *'how'* questions this research asks (how have seabirds become sentinels; how are they used to govern marine space; etc.) came to light in a slightly different and complementary way to other methods.

[18] For some examples, see: BirdLife International's Seabird Tracking Database, the Seabird Information Network, the SeaPop database, MoveBank, and Zooniverse's SeabirdWatch citizen science platform

3.4.5.2. On cliffs and at sea

> "You could spend hours staring at them – and I have – and know nothing more at the end than the beginning, except for an overwhelming sense of the mastery of the birds, the privilege of seeing them like this, not in crisis or ecstasy but in the midst of life" (Nicolson 2017, 24)

Within the peculiar pandemic constraints of fieldwork, I tried to also find other, more embodied ways of allowing seabirds and marine spaces into this research. As I described in the Introduction, the allure of an in-person encounter with an albatross drew me from my desk, with borrowed binoculars in tow, to the cliffs at Bempton in Yorkshire in the early summer of 2021. Although the albatross eluded me during my two days at the cliffs, this became somewhat beside the point as I became transfixed watching the other seabirds nesting there. The visit formed one of four I conducted to cliffs around the English coast, twice in the company of more experienced birdwatchers and RSPB staff, to attune to the lifeways of these birds. I spent hours watching as gannets, fulmars, herring gulls, guillemots, and other seabirds flew, rested, nested, and socialised around the cliffs, making field notes of what I observed and how I felt as I watched the birds. During wildlife watching boat trips in the Bristol Channel and Loch Hourn, Scotland, I watched fulmars and shearwaters engage in the dynamic soaring flight which enables them to journey across huge areas of ocean and integrate environmental information in the ways that make them important to scientists as sentinels (see Chapter Four).

Figure 4 - Gannets at Bempton Cliffs. Author's image

These trips to the coast and out to sea animate the descriptions of seabirds and seabird science I offer in this thesis. I found them both generative and frustrating. I came to relate to what some of my interlocutors described as the irresistible pull of seabirds, which had drawn them from other career paths towards these animals, but no great mysteries of seabird being yielded themselves to me in the way that I had hoped. Something nevertheless changed from my past encounters with these birds as data points on a screen or in the written accounts of scientists. If anything, I felt more disoriented than I had been while immersed amongst the semi-certainties offered by these mediations. I suspect this is a good thing, and to be anything else would have taken *considerably* more time, patience, and guidance. What I draw from these encounters and populate these pages with, then, are no great insights of my own about seabirds. Rather I have tried to see them, as Adam Nicolson describes above, not just as sentinels, populations in crisis, or the like, but as birds 'in the midst of life': as lively beings with their own agendas, always exceeding our attempts to know them.

Figure 5 - Seabird-fishery interactions in Loch Hourn, Scotland.
Author's image.

3.5. Analysis of research materials and 'writing up'

> "It is better to think that through analysis we make interpretations, not find answers."
> (Crang 2003, 127)

Interview transcripts, digitised fieldnotes, and documents were annotated and coded with NVivo and paper notes and maps through working iteratively between inductive and deductive modes of analysis. Qualitative data analysis software is undoubtedly a useful tool for this but at points I found it offered a little too much certainty – as if there was something true and unchangeable about the set of codes and annotations by which I had ordered the research materials. What started as open coding came too quickly to cement into schemas that seemed rather closed. It was useful and necessary at these points to spread notes out across the floor, highlight important statements, scribble, cross things out, sketch out code maps across A3 sheets, return to the annotated texts in NVivo, then back to the mess on the floor, and so on. Through this iterative process, some order would emerge. This was a new order, but it was not fashioned from *un*ordered materials; ordering begins from the formulation of research questions, choice of methods, and is actively co-constituted with participants who impose their own orderings and interpretations of events (see Crang and Cook 2007). Here, these layered orders were reflected on and worked through, and then with more reading, thinking, writing, and email exchanges with research participants, they were inevitably challenged, and contradictions or different directions emerged. Reordering, more notes across the floor and more edits to the coding schema on NVivo, would ensue.

In this way, the concepts that I was bringing to bear on the materials and the emic categories I identified never settled or made sense too easily – they were put 'at risk' in a correspondence between concepts, orders, and the research materials, and I learnt to notice and accept their deficiencies – and neither were they forgotten as I worked through stages of analysis. For example, I came to materials related to seabird tracking with a strong sense of this techniques' relationship to enhanced top-down surveillance and control over nonhuman life (see e.g., Bergman 2005; Collard 2018; Gillespie and Collard 2015). However, as I worked through the materials, this interpretation appeared increasingly insufficient to capture the diverse practices and logics associated with this technique, pushing me to expand my frames of reference (see Chapter Five). Written notes helped to record this evolving process, so that past ideas could be returned to. This proved particularly helpful when working across materials generated between the two stages of interviewing, whereby past ideas came to light in new ways. For instance, seabird conservationists interviewed in the first stage talked a lot about electronic monitoring technologies in fisheries, but their approach was very

different (and often more optimistic) compared with those of technicians and policy experts working with these technologies interviewed in the second stage.

Writing formed part of the process of analysis as itself a "method of inquiry" (L. Richardson 2000) rather than a separate stage in which findings were simply 'written up.' Indeed, writing entailed a lot of thinking, and concepts, interpretations, and structures were discarded or significantly modified quite some way into drafting the chapters. I started off trying to write three chapters into one, feeling as if everything had to be said all at once, before realising that the sub-sections of this messy behemoth (spies in the sky/spirits of the seas/eyes on the seas) were actually headings for different chapters altogether – to give one example. What is written up here, then, is not an innocent and transparent 'report on reality' (see Bingham 2003) but a way of composing my research materials that has proceeded in a not-dissimilar way to how I described analysis above. As above, an archive of drafts and parallel notes has allowed me to keep track of this process and to reintegrate ideas and text as appropriate. The resulting composition – this thesis – is therefore one of several possibilities and it does not preclude the possibility and validity of others. If it is successful, it will be modest in presenting my own interpretations and the generalisations I seek to make, and it will invite interpretations and lines of thought other than my own.

Moreover, in composing this text in the way that I have, there is much from my materials that is not directly included. These are what geographer Thomas Jellis (2023, 286) calls the "odds and ends" of research – "the fragments of notes, the miscellanea of drafts, the offcuts of applications, the keepsakes of fieldwork; in short, the archival remains of unfinished research." In volume and value, these odds and ends are significant; these majorities of notes, interview transcripts, and highlighted and annotated documents underpin much of what *is* presented in this research, even if they are not directly included in the text. They place an obligation on what is included; namely, that not only the best or most supportive examples are chosen but rather ones which honestly and reflexively speak to the research materials and process. In addition to these are the materials I did *not* have to work with; these pertain to a number of promising directions and cases which have not made it into the chapters. For example, in Chapters Four and Six I touch on British maritime imaginaries and their connections with colonial histories; there was undoubtedly much more

to say on this and its relations with the enactment of seabird conservation, but this would have required extensive archival research and training beyond the time and resources I had available here.[19] Various other directions, as I noted earlier, were curtailed by fieldwork constraints resulting from the pandemic. These were not completely absent from the writing process in that they influenced the claims I felt it was possible and reasonable to make. Hopefully, both these remaining materials and those which were tantalising but not sufficiently present do not signify an ending. They will be dusted off, pursued, and assembled into new forms, creating new odds and ends, and so on.

3.6. Summary

In this chapter, I have detailed the methodological approach through which this project was pursued and the sites and relations through which it unfolded. Extensive document analysis of research articles, scientific and policy reports, and news articles and popular media, 29 semi-structured interviews, participant observation at events and through 'go alongs', and varied practices of attuning to seabirds and marine ecologies were described as the principal methods. Thereafter, the iterative process of analysing and writing the materials generated through these methods was detailed. In the following chapter, I turn to the first part of my empirical analysis.

[19] Indeed, this is something taken up by geographer James Blair in his studies of conservation in the Falklands, and is also a concern of Bronte Evans Rayward's forthcoming doctoral research (see https://www.geog.cam.ac.uk/people/evans-rayward/) (last accessed: 20.09.23)

Chapter Four

“Samplers of the marine environment”

Seabird sentinels in three parts

4.1. Introduction

The bodies and sensory capacities of birds have long offered people ways of attuning to environmental processes and unfolding events beyond human perception. A diverse range of knowledge practices have been and continue to be associated with such bird sentinels, as I discussed in the Introduction. However, the practices and voices of biologists and ecologists have become particularly prominent in recent decades. Their research practices and the technologies they use to study birds are changing human-bird-environment relations and positioning birds as representatives of the ecological changes occurring in the Anthropocene, affording "unparalleled insight into the health of the natural world as a whole" (BirdLife International 2022, 14). The long-term population monitoring programmes and remote, in-situ, and wearable sensing technologies through which these insights are gleaned have added new layers to modes of knowing environments with and through animal bodies.

As scientists have sought to answer new and different questions about environments using birds, and the priorities and political economic contexts of environmental research have been in flux, so have framings of the birds involved. Tracing these interrelated transformations offers insights into the shifting character of environmental sensing practices in the Anthropocene. It is by now well established that these sensing practices have become increasingly digitalised, networked, and global in scope (e.g. Lehman 2019; Gabrys 2019). However, the intersections between the lived, sensory worlds of animals and human efforts to sense and understand environmental change are comparatively poorly explored in scholarship in the social sciences and environmental humanities (although see Forssman 2017; Gabrys 2016; Squire 2020). Insights into these intersections are timely because, as geographer Elizabeth Johnson cautions, new approaches to biomonitoring are implicated in powerful and problematic imaginaries of planetary management and neoliberal solutions to environmental crises, through which "the capacity to live and bear witness to that living becomes a productive enterprise"(Johnson 2017, 283; see also Barua 2021; Wakefield and Braun 2019). Moreover, as these approaches become increasingly data-driven, they risk excluding a broad swathe of "milieus, inventions, and becomings that might remain off the computational map, no matter how many more data points we add" (Gabrys 2016, 104). This matters for animals enrolled in environmental sensing practices—whose lives are materially

affected by new scientific approaches and the forms of governance they support—as well as for understanding the forms of expertise and experience called upon to comprehend environmental change and the new human and more-than-human relations inaugurated as a result.

This chapter grounds these concerns in an empirical focus on the scientific study of seabirds as sentinels from the mid-20th Century to the present. As I outlined in the Introduction, seabirds have incredible capacities to roam, forage, and live across terrestrial and vast atmospheric and oceanic spaces, and to adjust their lifeways in response to changing environmental conditions. These lifeways have been the subjects of myriad scientific practices. Indeed, seabirds are one of the best studied groups of marine species, with many of these studies focusing on the birds as sentinels of marine environmental conditions (Croxall et al. 2012). In this chapter, I offer an account of three ways in which seabirds are enrolled as sentinels – as populations, samplers, and platforms. These framings, used by seabird scientists, are interrelated, and have emerged as new scientific practices have looked to particular affordances of the birds in order to ask new questions about them and their environments. In particular, they stem from recognition of the environmental information seabirds integrate into their bodies through their foraging habits and ways of being. More recently, these framings also relate to the kinds of digital devices that can be attached to the birds. By tracing the emergence of these different framings and the contexts within which they have taken hold, the chapter addresses the research question: *"how and why have seabirds become sentinels?"*

I begin the chapter by considering the growth in long-term scientific studies of seabirds from the 1950s onwards, precipitated by the developing field of population ecology, which rendered the birds legible as populations and made changes in these populations discernible over time. Then, I show how the resultant data on seabirds came to be framed as useful sources of information on changing marine environments, and seabirds became framed as samplers of these environments. This section details how the seabird sampler emerged at the intersection between the lively capacities of the birds themselves, research pragmatism, and the knowledge and ignorance produced in the interactions between ocean science and political economy. The final section discusses the development of new satellite

surveillance infrastructures and telemetry and bio-logging technologies with which biologists and ecologists could follow seabirds out into their environments. These infrastructural and technological developments created the conditions for an emerging approach which bridges ecology and physical oceanography and uses animals equipped with sensors as platforms for oceanographic measurement. Taken together, the sections offer an account of how and why seabirds have become sentinels, and how this identity is itself multiple and has differed over time. In conclusion, I compare these three different framings and reflect on their implications for understanding the shifting character of environmental sensing, and on the chapter's contributions to literatures in the history of science and social scientific accounts of sentinel species.

4.2. Seabirds as populations

Over a series of expeditions between 1958 and 1964, British zoologist William "Lance" Tickell censused and banded the wandering albatrosses breeding at Bird Island, part of the British Overseas Territory of South Georgia in the South Atlantic Ocean. As Tickell was conducting his work, roaming and sitting amongst the great birds nesting on the grassy slopes of the island, he was also constructing a baseline against which variations in the birds' populations over time could later be perceived. It was against this baseline of data and subsequent studies that John Croxall, an ecologist with the British Antarctic Survey, was later able to identify a decline of 19.2% in the wandering albatross population at Bird Island between 1962 and 1978 (Croxall 1979). Croxall was not alone in observing such declines. At Possession Island in the Southern Indian Ocean, ecologists Henri Weimerskirch and Pierre Jouventin noted that the number of wandering albatrosses had reduced by 54% in 1986 from the approximately 500 birds counted in the field season of 1968-1969 (Weimerskirch and Jouventin 1987). These declines were concerning, and their causes uncertain. As Croxall (1979, 20) wrote, "whatever the proximate factors responsible for the decrease it is even less clear what the ultimate causes may be."

At the heart of understanding these changes and their influencing factors lies the field of animal population biology, which seeks to understand the factors influencing animals'

populations and how and why these populations change over time (Lewontin 2004).[20] Seabirds are easier than many other bird and indeed vertebrate groups to study as populations, owing to their coloniality and the relative accessibility of their colonies. They therefore became popular focal species for studies in animal population biology (Wooller et al. 1992). Birds more broadly have been central to developments in this field. For instance, some of the discipline's central figures during the 1950s, David Lack at The Edward Grey Institute of Ornithology in Oxford and Vero Wynne-Edwards at the University of Aberdeen, were particularly focused on bird populations and contributed to the development of some of the best-known long-term population studies of vertebrates – of great tits in Wytham Woods, Oxfordshire, and fulmars at Eynhallow Island, Orkney, respectively (Birkhead et al. 2014; Lack 1964). These studies, in turn, were predicated on an earlier set of developments. Most notable amongst these was bird banding, which had been first developed by Danish schoolteacher Hans Mortensen in 1899 and rapidly spread through networks of civic and professional ornithologists in the early 1900s (Benson 2017; de Bont 2015). Attaching numbered rings to birds' legs and recapturing them at a later date made it possible to identify and track individual birds and the fates of populations, such as the great tits' and the fulmars', over time.

Although in substantial disagreement over the drivers of population dynamics, Lack and Wynne-Edwards stimulated significant growth in population studies of birds, with their approaches and ideas percolating widely through ornithological and ecological scientific networks (Egerton 2015). Their influences can be traced, for instance, in the albatross studies discussed above. At the encouragement of Wynne-Edwards, George Dunnet at the University of Aberdeen initiated the fulmar population study on Eynhallow in 1950 (Birkhead et al. 2014). Jean-Louis Mougin, a French biologist from the Paris National Museum, worked with Dunnet on this study and transposed the methodology he became acquainted with there to

[20] It is essential to note here that population biology – particularly as it has been applied to human populations – has an extremely troubled history as a technology of often violent state power, which the uses I describe here contrast to but must be understood in the context of. Population biology has been used to define norms and deviance and as a justification to criminalise particular bodies and ways of being, even genocide (M. Foucault 2008; Rabinow and Rose 2006). Clearly, it has also been central to the often-problematic management of nonhuman bodies in conservation and natural resource management (Biermann and Anderson 2017). As anthropologist Heather Swanson (2019, 275) observes, "Population biology has a bad rap for good reasons."

his studies of seabirds during a posting to the French Southern and Antarctic Lands (Mougin 1967). One of these studies was of the wandering albatrosses at Possession Island, later continued by Pierre Jouventin and Henri Weimerskirch (2018). Similarly, after a posting as a meteorological assistant for the Falkland Islands Dependencies Survey, where he studied the islands' birds in his spare time, Lance Tickell collected his observations into an MSc thesis under the supervision of David Lack at Oxford before returning to study Bird Island's albatrosses (Cooper 2014).

Through such diffusions of both researchers and approaches, systematic studies of seabird populations began to proliferate across various sites from Europe to South Africa, South America, Aotearoa New Zealand and elsewhere (e.g. Boersma 1978; Brun 1979; Peat 2011; Wooller et al. 1992). These studies were buoyed not just by a growing interest in scientific field studies of animal populations, but also more broadly in monitoring changes in the environment over time. The perceived necessity of such ecosystem monitoring was bolstered significantly by the environmental movement of the late 1960s and growing awareness of human impacts on environments (Aronova 2015). Historian Elena Aronova (2015) has shown how existing international interests in biological surveying and censusing shifted during this period towards monitoring environmental *changes,* requiring measurement over time. The formation of the Global Network of Environmental Monitoring under the International Biological Program, and later the UNEP's Global Environmental Monitoring System (GEMS) were some prominent institutional manifestations of growing international interest in long-term environmental monitoring (Aronova 2015; Aronova et al. 2010). GEMS was premised on "a fact that, though obvious, has taken a long time to grasp, namely that natural-resource monitoring and natural-resource management are closely related and should go hand in hand", explained the system's Deputy Director, Michael Gwynne (1982, 40). Projects such as GEMS exemplified an understanding that effective environmental management rested upon monitoring, but also that the purpose of monitoring was to be significantly oriented towards the priorities of environmental management. This understanding was not entirely new, even if the scale at which it was manifesting was changing. For example, efforts to census and monitor bird populations had, already for some time, been shaped by the priorities of wildlife managers whose regional and

national management plans required data on the size and migration strategies of bird populations, particularly economically valuable species (see Benson 2017; Whitney 2014).

The value of approaches to studying animal populations and monitoring their dynamics and those of the wider environment over time was not equally appreciated by all. As with the causes of wandering albatross population declines, uncertainty and evidential sparsity complicated these studies and, indeed, were characteristic of much mid-century work on animal populations. British ecologist A. Milne (1957, 254) lamented in 1957 that "the student of animal population dynamics is confronted with an ever-growing literature which is a disheartening jumble of insufficient facts, alleged facts, ill-defined terminology, and conflicting theories." Studies attracted criticism for failing to identify key factors influencing seabird population change, or causal relations driving ecosystem processes (Wooller et al. 1992).

Population monitoring programmes which evolved out of these studies or used the data they had collected initially faced similar challenges and critiques. Not least amongst their detractors were some ecologists who considered them to be too simplistic and oriented towards management rather than the advancement of fundamental scientific concerns. Ecologists Robert Furness and colleagues (1993, 1) suggest that many early monitoring programmes suffered from "poorly-defined objectives and poorly-designed methodology, producing few or no useful results". Alongside purposeful research design, patience was a necessary quality for developing knowledge of seabird populations, because of the slow and long life histories of the birds which made population dynamics legible only over many years, even decades. However, advocates of collecting long-term observational data struggled to establish the timeliness and necessity of their work against the more 'fashionable' focus on hypothesis-driven experimental studies amongst ecologists and environmental scientists (see Aronova et al. 2010). Naomi Oreskes (2021, 492) has noted the difficulties faced by oceanographers whose studies were "viewed as 'monitoring' rather than 'research'" in attracting and maintaining sources of funding, whilst ornithologists have commented on the lack of funding in the second half of the twentieth century for monitoring programmes regarded as having "little academic respectability" (Furness et al. 1993, 1).

Nonetheless, the quantities of data on seabird populations continued gradually to grow, and the number of colonies studied increased with the modest funding available. Whilst in the 19th and early 20th centuries many seabird colonies had been an economically important resource, heavily exploited for their feathers and eggs (Barwell 2013), the pressures of direct exploitation no longer significantly concerned researchers. In many cases, there was little reason to believe that observed changes in productivity, mortality and overall species abundance were caused by pressures facing the birds on land. Rather, it appeared that they were controlled by conditions facing the birds at sea. For Weimerskirch and Jouventin (1987, 320), observing declining wandering albatross populations at Possession Island, it was therefore evident that the causes of these declines "must be looked for in the marine environment from which the birds feed, and not on the breeding grounds." Several researchers began to formulate this relationship between seabird populations and the marine environment as a potential opportunity. Ecologist Dee Boersma (1978, 1483) suggested, in one of the earliest examples of using seabirds to monitor marine environmental change, that "the breeding biology of seabirds may be useful reflections of long-term environmental conditions" in the oceans. Indeed, Furness and Monaghan (1986, 1), amongst others, noted an "exciting upsurge in seabird research" driven in part by this emerging concept of using "seabirds to indicate the damage we might be doing to our environment." In the following section, I show how this provided a new rationale to seabird population studies, which gained purchase as a result of a combination of the characteristics of the birds themselves which made them favourable for this approach, as well as the wider contexts within which seabird ecology and ocean science were taking place.

4.3. Seabirds as samplers

Whilst population biologists were centrally concerned with the factors driving animal population dynamics, a new concept began to emerge in the late 1970s and early 1980s, namely that population dynamics and the responses of seabirds to their environment and prey availability constituted sampled environmental information. This information appears in what science studies scholar Natalie Forssman (2017, 4) calls "fleshy traces" of the dynamic ecological relations between animals, their prey, and the physical environment, left in their bodies and reflected in their behaviours. These fleshy traces, as noted in the Introduction,

might appear as reduced survival amongst chicks or adults, poor growth rates amongst chicks, or – more drastically – large-scale abandonment of chicks by adult birds in response to reduced prey availability. Conversely, good or improving environmental conditions might be reflected in high survival and fledging success[21] rates. Ecologists William Sydeman and colleagues (2021, 982) suggest, then, that via their foraging behaviour, seabirds "accumulate and integrate, in a statistical sense, climatic, oceanographic and food-web variation...[and] provide immediate signals of changes in ecosystems that are difficult to observe directly."[22] By tracing this accumulated, integrated information, a picture of the condition and changes within marine ecosystems could be composed together with seabirds. The birds thereby took on a new identity amongst scientists as what ecologist David Cairns (1988, 262) , in one of the first papers proposing such an approach, refers to as cost-effective "marine sampling devices." Later, this came to be known by the term 'sentinel.' Furness and Camphuysen (1997, 727), for instance, suggest for the same reasons as Cairns that seabirds' accumulation of information from the marine environment makes them a "suitable choice to play a role as sentinel organisms: unexpected changes in their numbers, health or breeding success provide an alarm that may indicate an unknown pollution or food supply problem."

Although this identity as samplers was new to published research on seabirds, it can be found in a different form in the earlier practices of ornithologists. A crucial distinction is that it had previously been assigned to people: volunteer observers enlisted to band, recapture, and observe birds. Ornithologists in the 1910s viewed the practice of bird banding as potentially revolutionary in terms of the kinds of scientific questions that could be newly posed about bird migrations and life histories, and the novel possibilities to coordinate wildlife management at spatial scales previously unthinkable (Whitney 2021). Historian Raf de Bont (2015, 156-157) notes that these two projects were intimately linked in the minds of practitioners: "in order to successfully protect migratory birds (or rather to manage them as a natural resource) one had to trace their habits and whereabouts." However, to do so required a network of observers and observation stations exceeding the capacity and financial resources of professional ornithologists. The desire amongst these professionals to

[21] This refers to the number of chicks leaving the nest or being 'recruited' into the adult population.
[22] The same rationale appears in a number of review papers dealing with the topic of marine top predators as sentinels of environmental change. See Moore (2008) and Hazen et al. (2019) for examples.

amass large quantities of data on bird populations and migration routes in the 1910s and 1920s thus necessitated the development and maintenance of networks of volunteer observers, who could act as samplers across a large range and provide information at low cost to coordinating scientific organisations (Benson 2017). These observers facilitated ornithological data collection in ways and at scales that allowed both professional and amateur ornithologists to distance themselves from less rigorous and systematic natural history observations of the past and align themselves with a more self-consciously modern scientific project (Macdonald 2002; Toogood 2011).

In a comparable way, seabirds from the late 1970s onwards came to be understood as a valuable, widely distributed network of samplers who could contribute large volumes of data cost-effectively to scientists seeking to understand marine environmental conditions. Reflecting on the rationale behind these developments, Enriqueta Velarde (2019, n.p.) describes: "the birds will be your samplers, they will go out in every direction…and bring back information to the breeding area." Aside from the logics connecting these approaches, both also demonstrate, as historians of science interested in bird observation have shown, the ever-present wider political, economic, and social contexts shaping how and why birds have come to be studied and known in particular ways (e.g. Benson 2017; de Bont 2015; Macdonald 2002). Seabirds have often been presented as samplers owing to their highly visible nature—thus their ease of study—and the affordances I summarised in the Introduction. But to understand how such approaches came about and why scientists turned to seabirds to ask questions of marine environments, we also need to consider the wider political economic context implicated in reframing seabirds' characteristics and agency as valuable to this kind of science.

Leveraging seabirds as inexpensive ocean samplers can be viewed as an attempt by seabird researchers to both justify the studies they were carrying out, which, as discussed in the previous section, were not always well regarded amongst a wider community of researchers, and to direct more funding towards their ongoing and future work. As a predominantly ship-based pursuit dominated by "intrepid high-seas scientists from major research centres" (Lehman 2019, 617), the ocean science of the 1970s and 80s was an expensive pursuit. In contrast, as Cairns (1988, 268) argued, "seabird data are much cheaper

than assessment programmes that depend on research cruises because birds sample large areas of the sea without expensive ship time." Rather than an activity of limited wider import for which practitioners noted funding was "quite modest" (Dunnet 1991, 26), and "poor and declining" (Furness et al. 1993, 2), seabird monitoring was thus increasingly presented as a more cost-effective method of obtaining data that would illuminate the ecological effects of anthropogenic changes like overfishing and, towards the close of the century, climate change on the oceans (see Piatt et al. 2007).

This turn to seabirds as marine samplers reflects some dominant trends in post-World War II marine science funding, rather than a lack of funding *per se*. As geographer Jessica Lehman (2018) has shown, oceanographic science developed particularly rapidly during and following the 1957-58 International Geophysical Year (IGY) and the International Decade of Ocean Exploration in the 1970s. However, particular domains of knowledge were significantly privileged over others. During this same period, naval funding for oceanography in the US was particularly directed towards understanding the ocean as an arena of warfare; a physical, voluminous space through which energy, machinery, and people travelled (see Oreskes 2003; 2021). As the principal funders of oceanographic research, navies privileged the development of the physical branch of oceanography, capable of producing knowledge aligned with their aims. In some instances, as Elizabeth Johnson (2015) and Rachel Squire (2020) note, understanding marine life was important to military interests, contributing to biomimicry and underwater inhabitation by military personnel, for example. More often, though, biological research did not benefit from the lucrative funding opportunities available to many physical scientists, creating a new disparity and separation between biological and physical ocean science which had not previously existed to the same extent.

This fostered a situation, historian of science Naomi Oreskes (2021, 496) argues, in which scientists at oceanographic institutions during and after the Cold War "literally did not know how many fish there were in the sea"; partly because they were not asking these questions and partly because there was not the technical capacity to do so, both functions of available funding. This goes some way to explaining why the early focus on seabirds as sentinels focused particularly on their capacities to sample and reflect marine food supplies

(i.e. fish stocks) as the state of fish stocks and the food webs they were embedded within was poorly understood.

Despite few examples of direct military interest in seabird research,[23] military activities did offer opportunities for expanding this research into new spaces. During the period between the 1950s and 80s, much of the infrastructure established in these Southern latitudes by military and colonial agencies was repurposed to fulfil more scientific priorities, and organisations tasked with researching and surveying these spaces changed hands to government research agencies. Asked in an interview how seabird monitoring began in the French Southern and Antarctic Lands, seabird ecologist Davide responded:

> "for historical reasons and probably geopolitical reasons we have a permanent presence in these remote islands and there is a polar institute that is sending people there so there are the reasons why we study there: they want a military presence on these bases and the science is probably a way to value this presence, make something out of it." (interview, 26.08.2020)

Moreover, the Falklands Islands Dependencies Survey, under which Lance Tickell carried out some of his seabird research, began as a World War II mission of the British Admiralty under the name 'Operation Tabarin,' before being transferred to the British Government's Colonial Office and tasked with cartographically bolstering British claims to South Atlantic and Antarctic lands (Dodds 1996; 2002). Later, in 1967, the organisation was transferred to the Natural Environment Research Council under a new name, the British Antarctic Survey (BAS). As Jessica Lehman (2019, 619) has argued, the production of scientific knowledge about the oceans is inextricably linked with "imperial networks refracted through the politics of the Cold War." As BAS ecologist Arthur suggested in an interview, both the figures involved in shaping the development of seabird population research discussed in the previous section, and the histories shaping the presence of researchers in particular spaces, mean that, "the most active players in seabird research in the Southern Ocean are these ex-colonial powers" (interview, 26, 03, 2021). Without the particular history placing researchers in Southern

[23] The Australian Naval Airbase HMAS Albatross and the US military's Grumann-HU16 Albatross aircraft, as well as Benson's (2010) account of US naval interest in albatross tracking for facilitating safe landings of their aircraft at Midway Atoll offer some counter examples. Indirectly, the Royal Naval Birdwatching Association established in 1948 also tied together military personnel, if not agendas, with the lives of seabirds.

Ocean spaces, it is likely that the wandering albatross declines described earlier would have gone unnoticed for much longer. With this in mind, we come to see that seabirds' newfound identities as samplers were as much a function of the political economic contexts they were embedded within, as they were related to their unique capacities to sample information about the marine environment. This becomes even more evident when we consider the outcomes of the research itself.

Amongst those who started to consider this seabird-sampled information more interesting were management authorities tasked with environmental monitoring under financial constraints and limited operational capacity. The Scientific Committee for Antarctic Research 1978), for example, recommended regular monitoring of seabirds as "the best prospect for identifying changes in the abundance and distribution of prey stocks and especially those changes that may arise following the advent of commercial exploitation of krill." The body tasked with managing these stocks, the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), came to incorporate this recommendation into their own data collection and ecosystem-based management strategies (Agnew 1997). CCAMLR was not alone in turning to seabirds as nonhuman samplers. In an interview, Michel, the seabird ecologist introduced earlier, explained how his group's research had changed as a result of this growing interest in seabirds as samplers, or what he calls 'monitors':

> "The scope of the study that we did in Crozet and Kerguelen[24] changed a lot with the interest in global change, especially climate change. We realised we can use these species as a monitor of the environment, so you can gain information on the environment through the demography of this animal […] and now we have this long-term study that allows us to address a lot of questions. But at the beginning it was considered just as some basic demography and a lot of people considered it was not very interesting." (interview, 01.03.2021)

Seabirds were an important group of animals in this respect, but not the only ones that management authorities were turning to for information about the marine environment. For instance, the US Environmental Protection Agency funded a "mussel watch" proposed by Scripps Institute of Oceanography scientist Ed Goldberg, which involved monitoring mussels

[24] Crozet and Kerguelen are island groups in, and territories of, the French Southern and Antarctic Lands.

at 100 coastal sites around the US as sentinels for local pollution and the status of US coastal ecosystems (Goldberg 1986). In initially calling for its development, Goldberg (1975, 111) promoted the cost-effectiveness, simplicity, and repeatability of the mussel watch concept, in contrast to the "many proposed global marine monitoring programmes… characterized by their vastness and complexity which lead to their doom as fantasies on paper" – mirroring the arguments made by Cairns and others about seabirds.

Yet efforts to monitor environments with seabirds and other nonhumans were accompanied by their own complexities and ambiguities. As much as they were made possible by the data collection and population studies that preceded them, studies using seabirds as samplers were also constrained by them. Cairns, for example, *hypothesised* on the relationships between prey species availability and seabird population and behavioural responses based on existing monitoring data relating to parameters of survivorship, breeding success, chick growth, colony attendance, and activity budget. However, he also noted the speculative nature of this exercise, given that "seabird response to prey availability has not been widely quantified" (1988, 262). Seabird ecologists Wooller, Bradley, and Croxall (1992, 111) elsewhere described available evidence about how seabirds respond to changes in the marine environment as "equivocal", "complex", and "ambivalent." Whilst there existed significant data on different seabird parameters (such as breeding success, survivorship, etc.), how these responded to environmental conditions and thus what kinds of fleshy traces of environments they actually constituted remained poorly understood. A revisit to Cairns' hypotheses shows more complex, non-linear relationships than those he predicted and concludes that "much uncertainty remains about using seabirds as indicators" (Piatt et al. 2007, 232). The birds themselves challenged their newfound identity, and the enthusiasm of early studies became gradually tempered by greater conservatism.

4.4. Seabirds as platforms

The problems of attributing causal relations and generating useful information for management and monitoring, which we saw affecting mid-twentieth century population biology, thus still haunted the more contemporary studies aiming to use seabirds as marine samplers. Ecologists Rory Wilson and colleagues (1994), for example, acknowledged that

because seabirds respond to environmental variability, they *could* be useful for monitoring environmental change where other forms of monitoring are logistically, technologically, or financially infeasible. However, as above, they considered that such approaches frequently produce ambiguous results because various environmental factors contribute to population dynamics and the responses of seabirds to environmental variation are often non-linear (see also Piatt et al. 2007; Wooller et al. 1992). As such, they suggest, "to eliminate the need to interpret among multiple, complex interacting factors, animals should be used to monitor environmental variables *directly*" (Wilson et al. 1994, 199, my emphasis).

4.4.1. Infrastructural developments

Contrary to Goldberg's pessimistic predictions in the previous section about global marine monitoring programmes, various satellite earth observation systems and international ocean sensing networks such as the Argo programme of drifting sensor floats have flourished and proliferated into the 21st Century (Lehman 2018). Compared with this range of technologies and the quantities of data available to environmental scientists now, the image of researchers observing birds with their binoculars and other instruments on weather-beaten cliff faces seems almost quaint, if not antiquated. It is tempting to imagine that environmental monitoring with animals is therefore a product of a particular period prior to the development of these infrastructures. However, towards the closing of the 1980s, some major technological developments in satellite infrastructures and wearable sensing devices opened novel opportunities for researchers studying highly mobile animals such as seabirds and facilitated enrolling these animals into increasingly digitised assemblages for environmental monitoring (Jouventin and Weimerskirch 1990; Wilson et al. 2002).

In 1978, the Argos satellite-based surveillance system was launched as part of an international collaboration between the US National Aeronautics and Space Administration (NASA), the Centre National d'Etudes Spatiales (CNES) and the US National Oceanographic and Atmospheric Administration (NOAA). The system was to be dedicated primarily to environmental monitoring, a first of its kind. Etienne Benson (2012) has offered a detailed history of this surveillance infrastructure and the actors assembled around it. In Argos' early years of operation, Benson shows, meteorologists and physical oceanographers dominated

the system's user base. The system, its instruments, data standards and processing algorithms were substantially influenced by the demands and priorities of these more influential, better-organised physical scientists (Benson 2012; see also Oreskes 2021). Other research communities were also extremely interested in accessing the Argos system and the benefits it might bring to their fields of enquiry, prominently amongst them wildlife scientists. Yet designing transmitters that fulfilled the standards required by physical scientists whilst being small enough to attach to animals proved challenging. This largely excluded biologists from using the system in its first decade. As Benson (2012, 855) notes, "the costs were daunting, the amount of useful data collected before the tags failed was negligible, and the impact of the tag on the behaviour of the animal almost always in question."

Without appropriate tracking technologies, a mix of speculation, ship-based surveys, and recovery of rings from dead birds characterised scientific attempts to know seabirds' mobilities pre-1990. One of the more outlandish approaches involved colouring birds with pink dye and soliciting reports of pink birds from commercial vessels, which saw limited success (see Tickell 1968). In a study from Kerguelen Island in which a total of 3,989 birds were dyed, "The ratio of the number marked to the number subsequently sighted [was] 174:1" (Weimerskirch et al. 1988, 217). Able to provide a broad impression of birds' distributions, these approaches nevertheless left seabirds' mobilities as a crucial missing piece of information in understanding the links between the birds and their marine environment. As British Antarctic Survey ecologist Anne (interview, 12.2.2021) explained to me: "say you know what the population trends are at the colonies and you've got one colony that's declining very rapidly and one that's relatively stable, and you think most of the threats they're facing are at sea, then it becomes a lot easier to work out the implications if you know where the birds are going and where they're coming from." The motivation for overcoming the technical barriers described above was therefore significant.

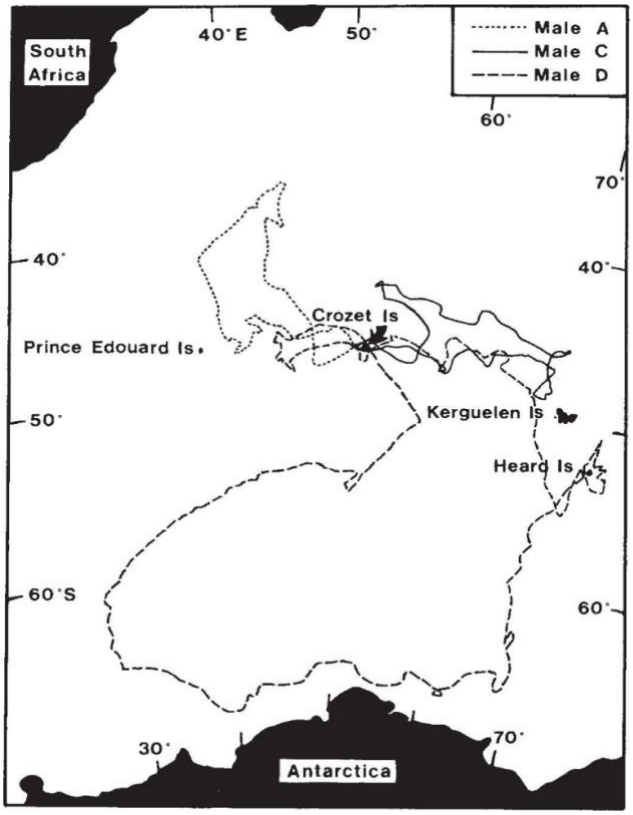

Figure 6 - Map showing tracks of three wandering albatrosses in the Southern Indian Ocean. Reproduced from Jouventin and Weimerskirch 1990 with permission from Springer Nature, license no. 5777630182944

In the first year of Argos' launch, the Scientific Committee on Antarctic Research Working Group on Biology (1978, 43) "invited the chairman of the Subcommittee on Bird Biology [then French biologist Jean Prevost] to discuss with CNES the possibility of developing effective instrumentation for tracking individual sea birds," noting that radio-telemetry techniques then used for wildlife tracking were not suitable to the task. It was not until 1990, however, that a breakthrough in animal satellite telemetry realised by Pierre Jouventin and Henri Weimerskirch offered an opportunity to do so. Japanese company Toyocom Ltd had recently designed Argos transmitters for use with dolphins, which the pair acquired and modified to fit to the wandering albatrosses they were studying at Possession Island (Jouventin and Weimerskirch 1990). Researchers have since reflected on the uncertainty surrounding this early work. For example, Michel explained to me that there had been some trepidation because these tags "didn't work with the dolphins" (interview, 01.03.2021). They worked with the albatrosses, however, and the resultant data showed the tracked birds

covering between 3,600 and 15,000km in single foraging trips, traveling at speeds of up to 80km per hour (Jouventin and Weimerskirch 1990; see Figure 6 above).

Beyond distances and speeds though, the tracking data demonstrated which oceanic areas the birds were visiting. This became centrally important to establishing that the population declines discussed earlier were linked to growth in commercial longline fisheries in these areas, where birds were being unintentionally hooked and drowning in large numbers (as discussed in the Introduction). Jouventin and Weimerskirch's study inaugurated a period of rapid expansion and experimentation with telemetry technologies for studying seabirds' mobilities. Researchers benefited from the fast-paced development of tracking devices concurrently taking place in other fields, such as small wearable GPS devices for sports like running which were coincidentally the right size for using on seabirds, and upgrades to the Argos system and its organisational structure favouring a broader array of environmental applications beyond the physical sciences (Benson 2012). Where early devices were highly bespoke and expensive, these cheaper, mass-produced devices dramatically increased the accessibility of telemetry technologies. As with the mass deployment of numbered bands on terrestrial birds in the early 1900s across Europe and North America, there was a feeling of revolution in the air with regards to the new understandings these devices might render possible. Jessica (interview, 17.09.2020), an ecologist working on seabird tracking, explained to me that this precipitated "a period when everyone put them on the birds, huge numbers of devices were put out, and this went on for a considerable amount of time because people wanted to know, and now it would be rare to find a site with a big seabird study where they haven't deployed GPS to find out where they go." Having answered basic early questions about the birds' mobilities, researchers began experimenting with other wearable devices aimed not only at locating the birds, but also collecting data about the environments through which they moved. These studies appeared to offer a more direct way of sensing environments, without the complexities and uncertainties of interpreting the fleshy traces they left in animals.

4.4.2. Physical-biological synergies

At first, those involved with these studies, which extended beyond seabirds to a range of mobile marine animals including seals, whales, and turtles, were primarily biologists.

However, they were keen from the earliest stages to raise the profile of the approach with physical scientists and envisioned "a new synergy between biological studies of marine vertebrates and oceanographic studies used to describe and predict changes in the ocean atmosphere system" (Fedak 2004, 133; see also Fedak 2013; March et al. 2020).

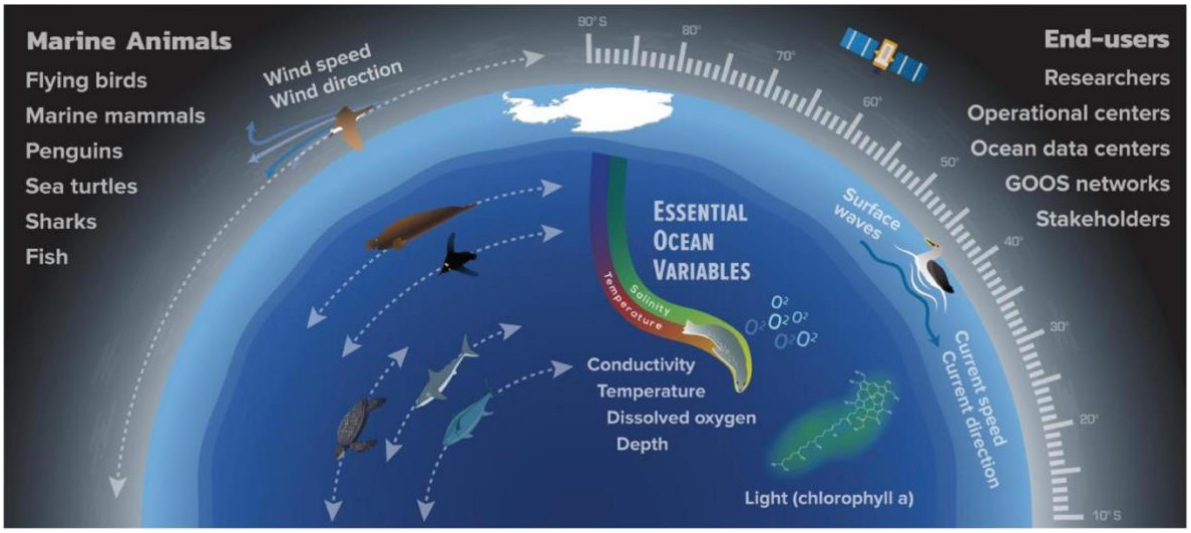

Figure 7 - An illustration of the environmental variables that can be measured using animal-borne sensors. Reproduced from McMahon et al. 2021 under a Creative Commons Attribution 4.0 International License. https://creativecommons.org/licenses/by/4.0/

This was not accurately a new synergy, but rather a realignment of the concerns of biological and physical ocean science made possible by new sensing devices and infrastructures like Argos. Mike Fedak (2004, 133), a marine ecologist at the University of St Andrews, summarised this as not only a new possibility but a necessity:

> "Biologists realize that without such integration, they will not understand how ocean processes shape the life histories of the beasts they study and how they affect the status of their populations. Ecosystem managers, environmental policy makers and conservationists know that without integration of the biological and oceanographic information, they can not make sensible decisions about management regimes. Furthermore, as the demands of operational oceanography increase, oceanographers will search for new cost effective, innovative technologies to fill the gap between data requirements and the resources provided to collect that data."

At the intersection between the concerns of biologists, oceanographers, and managers were the bodies of marine animals, reimagined as "platforms" for the collection of oceanographic data (see Benson 2011; Forssman 2017). Through their instrumentation with various sensing

devices, animals were not only reimagined but also materially enacted as platforms—their mobile bodies literally becoming part of the material infrastructures of ocean sensing and integral to the enactment of new interdisciplinary ocean science (see Figure 7). Weimerskirch and colleagues (1995, 299) suggested in an early study trialling such approaches, for example, that new miniaturised data loggers attached to seabirds turned them into "cheap platforms" for measuring oceanographic parameters such as sea surface temperature directly and capable of filling gaps in under-sampled areas. Whilst early approaches were largely proofs of concept, the use of animals as platforms for oceanographic monitoring is being institutionalised within such large-scale initiatives as the Animal-Borne Ocean Sensors (AniBOS) network, part of the Intergovernmental Oceanographic Commission's (IOC) Global Ocean Observing System and the UN Decade of Ocean Science for Sustainable Development (McMahon et al. 2021).

4.4.3. From samplers to platforms

On first pass, the platform and sampler are similar framings of seabirds, particularly regarding the continuity of narratives of cost-effective environmental monitoring. The platform might be regarded as simply a digitally-enhanced sampler – allowing the specification of location and the direct measurement of environmental parameters via new miniature digital sensing technologies. However, I suggest that there is a more significant difference at play in these new framings. For Benson (2012, 860), as for Fedak (2004) above, animal platforms evidence a "rapprochement" of biological imaginaries of the environment as a web of life and the physical sciences' volume of flows – rapprochements that are becoming increasingly common under the framework of Earth System Science and its aspirations of joined-up knowledge of coupled, planetary systems comprising physical, biological, and anthropogenic components (e.g. Lövbrand et al. 2009). The species- and site-specific ecological research associated with the seabird as sampler was not – to articulate a first difference between these framings – initially aimed at producing this kind of knowledge, although ecologists are increasingly integrating localised seabird monitoring datasets into syntheses offering global pictures of change (see Sydeman et al. 2021).

A second, perhaps more significant difference relates to how these projects promise to overcome the messy ecological complexities and indeterminacies in animals' responses to their environment that have been a constant presence in the approaches explored thus far. As Jennifer Gabrys (2016, 101) writes of projects using animals as sensors, animal bodies and behaviours come to resemble "the operations of the technical milieus of technical objects, since animal sensing becomes equated with computational sensors". The complexities of ecological relations "are transformed into informational exchanges through computational sensor networks" (ibid), assembled here to produce global ocean knowledge. The desirable characteristics of particular species come to be shaped by these computational logics, which foreground more technical concerns around device weight, size, and battery life, which influence which species devices can be attached to (see Adams 2020). Animals are preferentially selected, not necessarily for their environmental sensitivity, but for the ability to attach sensing devices to them (accessibility), the ability to carry devices (size), the ability to sample large areas (mobility), and the ability to retrieve devices (predictability/site-fidelity). For instance, several researchers described to me favouring wandering albatrosses as platforms for oceanographic monitoring because of their large size, ease of study and capture, and wide-ranging mobilities.

Interoperability becomes a key concern here. As one of many platforms used for oceanographic monitoring, researchers from across the biological and physical sciences have been keen to ensure that the data collected by animal platforms differs as little as possible from that collected by other platforms. Indeed, scientists directly compare the number of measurements collected by animal-borne sensors with those collected by other sensors like Argo floats, and refer to the more complete coverage of the oceans instrumented animals will provide by traveling into spaces that are poorly sampled by satellite remote and in-situ sensing (Hazen et al. 2019; McMahon et al. 2021). In doing so, they spell out a new role for animals in relation to international institutional visions for "comprehensive monitoring of the ocean" (Harcourt et al. 2019, 215), but it is perhaps one which is less interested in animals themselves and more in how they might be made to align with the computational logics of these visions. The framing of seabirds as samplers is centrally interested in animals and the kinds of environmental information they express through their bodies and behaviours (and in their deaths and failures to live well, which become the signals of change scientists are

looking for). These platform approaches, even as they require a living, sensing, experiencing animal body to sense environments in the way that they do, are nevertheless arguably interested less in the lifeworlds of the animals involved than the standardised oceanographic data that might be collected with them. This does not necessarily diminish the role of the animal as a sentinel of environmental change. However, we might ask how the warning signals of environmental change that such animals express are altered by their mediation through these computational infrastructures, and whether – as considered in the following chapter - these approaches configur the functioning of animal sentinels in wholly new ways.

4.5. Conclusion

This chapter has traced three different ways in which seabirds have been made legible by scientists since the 1950s: as populations, samplers, and platforms. Each of these, following Annemarie Mol (2002), entails a different enactment of seabirds and together they suggest a need to understand environmental sentinels as multiple, enacted differently through different practices and more-than-human collectives. These framings have emerged and developed in response to the contexts shaping the production of knowledge about the oceans and about animals' lives. They have also been shaped by the people, methodological approaches, and technological infrastructures implicated in seabird research, as well as the birds themselves (see Table 3). Particularly noteworthy is that while the roles of animals in human-conceived ocean sensing projects have *changed*, they have not diminished over this time. Narratives of comprehensive ocean monitoring enabled by new digital technologies have not turned away from animals but have instead embraced them as valuable in new ways.

Table 3 - A comparison of seabirds as populations, samplers, and platforms

	Populations	*Samplers*	*Platforms*
Characteristics	Coloniality; Life history traits	Coloniality; Life history traits; Trophic position; Responsivity to food supplies/ecological change	Size; Mobility; Distribution; Behavioural traits - ease of study/handling;

			Interface with digital devices
Methods	Population censusing; Time-series data collection	Time-series data collection; Measurement of growing number of variables; Basic statistical modelling	GPS tracking; Biologging; Complex modelling
People	Population biologists/ecologists; Explorers/expedition scientists; Volunteer observers	Seabird ecologists; Management agencies (e.g. CCAMLR)	Seabird ecologists; Physical oceanographers; Data technicians; International scientific and management agencies (e.g. IOC)
Context	Post-World War II; Empire/overseas territories; Modernisation of field sciences e.g. ornithology	Cold War; Naval research funding and facilitation; Growing awareness of environmental change/1970s environmentalism; Establishment of environmental monitoring programmes (e.g. GEMS)	Anthropocene; Growth of Earth System science; Digitalisation of sensing and development of satellite earth observation infrastructures (e.g. Argos)
Logics	Scientific – understanding population dynamics; Economic – wildlife management (e.g. of economically valuable species)	Scientific – Ecological; Political - Environmentalist; Managerial; Economic – cost-effectiveness	Planetary monitoring; Computational; Economic – cost-effectiveness

My analysis has distinguished between these different framings of seabirds temporally, which partly reflects that they have emerged successively at different historical junctures and in relation to distinctive political economic contexts. However, this distinction is also partly heuristic. Indeed, ecologists continue to conceive of the seabirds they study in all three ways. Population monitoring studies, many of them now several decades old, continue and the notion that seabirds sample information from the environment independently of wearable digital devices persists (see Velarde et al. 2019), even as the

manifestations of seabirds as platforms diversifies and becomes more established within multi-disciplinary ocean observation initiatives. Whilst this continuity might be understood as an ongoing gesture of humility – a recognition that much remains "beyond the reach of human senses" (Kosek 2010, 656) and a valuation of 'multiple modalities' of sensing environments, as some scholars have suggested biosensing is (Gabrys, 2019; Gramaglia and Sampaio da Silva, 2012) – it is not to be embraced uncritically.

Distinguishing these approaches problematises scientific accounts which designate animals as, simply, suitable sentinels or not (for some marine examples, see e.g. Hazen et al. 2019; Moore 2008), without consideration for the particular historical and political economic contexts and epistemological commitments which weigh upon such designations. As anthropologist Jake Kosek (2010, 651) writes about the uncertain causes of bee declines, "Few researchers […] are systematically situating the crisis, whatever its cause, within historical, economic, and political relationships between bees and humans." The same is true here and is something I have addressed by reading seabird sentinels through the lenses of work on the geographies and histories of ocean science, ornithology, and environmental monitoring. I have added to histories of ornithological science a more contemporary focus on how digitalisation and powerful emerging framings of the planetary in the late-20th century have configured the production of knowledge with and about birds, implicating them in broader shifts in environmental sensing practices in the context of the Anthropocene. Moreover, I have cultivated a greater awareness of birds themselves – which are often a backdrop to human affairs in these historical literatures – and how their particular lifeways have shaped the knowledge practices and politics described.

When scientists refer to seabirds in the ways I have laid out here, at issue are not only abstract signals of environmental change attained through new more-than-human sensing practices, but also a global crisis in seabird populations and individual birds struggling to adapt to changes in their environments. This deterioration of unique "flight ways" (Van Dooren 2014) has been caused in large part by the same historical, political, and economic dynamics which have stimulated scientists to study seabirds in the ways that they have. These are issues which "a growing appetite for scholarly reflection about birds" (Petri 2023, 4), and particularly an emerging avian research agenda amongst more-than-human

geographers (see Petri and Guida 2023; Turnbull and Wrigley 2023), is well positioned to explore further. This might fruitfully be achieved in conversation with existing work attentive to the processes through which particular beings are designated as sentinels and the effects these have had on responses to environmental issues (see Benson 2013; Gramaglia and Mélard 2019; Lakoff 2016). Ultimately, attending to questions of how and why seabirds *become* sentinels opens up opportunities to identify what the more-than-human implications of their status as such might be as well as how they might become otherwise, whether as new kinds of sentinel or something else entirely. These considerations are taken up in the following chapter where I explore the implications of operationalising seabird sentinels for the purposes of surveillance and control of the fisheries which threaten their existence.

Chapter Five

“Spies in the sky”

Operationalising albatrosses for fisheries surveillance

5.1. Introduction

Between 2015 and 2019, a team of seabird ecologists led by researchers at the Centre d'Etudes Biologiques de Chizé (CEBC) worked with the Aotearoa New Zealand-based company Sextant Technology to prototype and deploy new biologging devices intended to detect the fine-scale interactions between albatrosses and fishing vessels. These devices were attached to 169 wandering and Amsterdam albatrosses breeding across the Crozet, Kerguelen, and Amsterdam Islands, sub-Antarctic outposts of the French state in the Southern Indian Ocean (Weimerskirch et al. 2020). By combined location and radar detection functionalities, the devices were intended to enable both tracking the movement of albatrosses and identifying their interactions with fishing vessels by detecting those vessels' navigational radar emissions. This information could be transmitted to the researchers in near-real-time through the Argos satellite infrastructure.

Studying the first datasets collected by the birds, which had journeyed over vast areas of ocean extending to Aotearoa New Zealand and South Africa, the researchers observed several discrepancies between the radar detections they were recording, and the location data on licensed fishing vessels provided to them by marine management authorities. This suggested that the birds were encountering illegally operating vessels, the locations of which could be identified by the devices. Initially conceived of as a study to improve scientific understandings of albatross-fishing vessel interactions, this finding changed the project's direction. The researchers applied for a European Research Council Proof of Concept grant in which they proposed combining the characteristics of albatrosses – large, wide-ranging birds often attracted to fishing vessels in search of food – with the sensing capacities of their new devices, to develop an 'Ocean Sentinel'.[25] The Ocean Sentinel project proposed "to use animals as platforms to make research operational, especially for large-scale surveillance [of fisheries]" (Weimerskirch et al. 2020, 3007). By collaborating with French government agencies responsible for administering the French Southern and Antarctic Lands and coordinating marine surveillance activities within them, the project intended to identify (illegal) fishing activity and make this activity amenable to control in a novel way. In doing so,

[25] More information on the grant can be found at: https://cordis.europa.eu/project/id/780058 (last accessed: 15.03.23)

Ocean Sentinel 'operationalises' the concept of animal sentinels, turning it into a governance technique which I term 'on-bird surveillance.'

Developments relating to 'Smart Earth' technologies, broadly defined as the environmental applications of the Internet of Things, have been centrally positioned as answers to several pressing challenges in ocean governance from overexploitation of fish stocks to plastic pollution and marine biodiversity loss (Bakker 2022; Drakopulos et al. 2022). These technologies are creating the conditions for substantial changes in oceanic knowledge production and governance. For instance, they open up novel opportunities for automated monitoring and real-time responsivity captured by the term 'smart oceans governance' (Ritts and Simpson 2022). These technologies are also implicated in the growing prominence of ideas that digital environmental surveillance and governance are essential for maintaining healthy ocean ecosystems. Scholarly accounts of digitised oceans have focused particularly on their monitoring by satellites and in-situ and robotic sensors, as well as on oceanographic models (see Gabrys 2019a; Helmreich 2019; Lehman 2018; 2020). Through these digital technologies, ocean surveillance and governance practices are performed by a "composite figure of distributed human and nonhuman agency" (Amoore and Raley 2017). However, the conceptualisation of nonhuman agency in these accounts remains distinctly technological. Little attention has been paid to the roles that animals, instrumented with various sensing devices, increasingly play in these ocean governance assemblages. Moreover, whilst there has been some parallel critical scholarly interest in developments in animal tracking and biologging techniques such that animals are not only sensed, but environments are sensed *with and through* them (see Benson 2011; Forssman 2017; Gabrys 2016a), how such approaches are being retooled to directly serve particular governance purposes has been little explored.

This chapter critically explores the ways in which animal sentinels become operational in the governance of ocean space and what the implications of this may be. It responds to the research question: "*how are seabird sentinels used to govern ocean space and with what consequences?*" In addressing this question, I develop recent calls to investigate novel 'operational ecologies' – "emerging and experimental sites of environmental enclosure, control, intervention and exploitation […] designed to fix, manage or transcend contemporary

environmental turbulence" (Lockhart et al. 2023, 4) – enabled by digital technologies and infrastructures. My empirical focus is on the Ocean Sentinel project introduced above, the established albatross tracking techniques from which it has emerged and diverges, and the broader relations between albatross conservation efforts and the governance of commercial fisheries. I suggest this offers a compelling focus for considering the emerging role of sentinel animals in conservation practice, and for analysing the features and tensions of novel forms of ocean governance.

The chapter first considers the emergence of a new ocean governance paradigm which is attentive to the spatiotemporal dynamism of the oceans and the agencies of marine life, known as 'dynamic ocean management.' I suggest a different framing of these approaches than that which has been foregrounded in recent geographical literatures, drawing on engagements with an emergent environmental mode of biopower evident in contemporary environmental governance practices. Ocean Sentinel is understood in relation to these dynamic ocean management approaches, and as a response to the perceived deficiencies of existing approaches to mapping overlaps between albatrosses and fishing activity. I then discuss Ocean Sentinel as a project which operationalises albatrosses for the performance of fisheries surveillance in a way that is balanced between an understanding of these birds as surveillance *technologies* and surveillance *agents* or 'albatross cops.' In the penultimate section, I consider a series of implications – for animals, marine resource users, and the relations between different actors in ocean governance – that follow from this approach, before turning in conclusion to identify a set of developments in research and practice which promise ways to better conceptualise and shape such novel ocean governance approaches.

5.2. Dynamic Ocean Management

A subset of the smart ocean governance approaches introduced above are grouped under the term 'dynamic ocean management' (A. Hobday and Hartog 2014; Lewison 2015; Maxwell et al. 2015). These approaches are characterised by their focus on monitoring marine ecologies and human activities – such as the movements of fishers or freight traffic - in near-real-time using computationally intensive methods, and developing management approaches

which accommodate for, and respond to, mobilities and change as they occur. Whilst in their relative infancy compared with more established marine management approaches like static marine protected areas and other area-based management techniques, these approaches are gaining traction. They respond to a desire on the part of researchers and marine managers to identify ways to monitor and govern an ocean that is increasingly turbulent, dynamic, and depleted, and also to a recognition that, perhaps, mapping and managing the oceans according to spatiotemporally fixed approaches imported from terrestrial settings has always been inappropriate. Marine ecologists Sara Maxwell and colleagues (2015, 42) summarise the rationale behind these approaches when they suggest that, "to be most effective marine management must be as fluid in space and time as the resources and users we aim to manage."

Several fully operational dynamic ocean management systems have already been implemented across different contexts; for instance, the TurtleWatch bycatch programme in Hawaii; tuna fisheries management in the South Australian Bight; and the prevention of noise disturbance and ship collisions with northern right whales in Eastern Canada and killer whales in the Salish Sea (Bakker 2022; Maxwell et al. 2020; Ritts and Simpson 2022). In these examples, oceanographic and animal-borne sensors and the data they generate are used to monitor marine ecologies and resource users and control human activities, through dynamic marine protected areas or real-time modulation of shipping traffic and fishing effort in relation to the movement of protected species. These approaches build upon the research projects discussed in the previous chapter which have enlisted marine animals as 'oceanographers' or 'animal platforms' for collecting oceanographic data (Fedak 2004; Forssman 2017). More radically, they extend these approaches by integrating animals not only into the sensing infrastructures of ocean observation, but also operationalising them in the performance of ocean governance.

Geographers, who have argued that existing approaches to marine management poorly account for the dynamism of marine ecologies and human resource users (see Bear and Eden 2008), have become increasingly interested in these approaches for their potential to enact a 'wet ontology.' This is a notion initially mobilised by geographers Philip Steinberg and Kimberley Peters (2015, 253) to account for "the ocean's biogeochemical processes

[which] are resistant to a terrestrial ontology of bounded zones and emplaced points of power and knowledge," and to outline how the ocean's voluminous, liquid, and turbulent properties might re-enliven social theory. Scholars have pointed to the potential for dynamic ocean management to enact such a wet ontology in practice through management approaches which are "sensitive to the heterogeneity of actants and forces, alert to fluidity and questioning of fixed boundaries" (Bear 2017, 29; see also Peters 2020). The case I engage with primarily in this chapter – the Ocean Sentinel project introduced above – both exemplifies these emerging ocean governance approaches and, as I expand upon below, differs from them in marked ways. It thus orients me towards a slightly different set of concerns than those articulated by geographical engagements with dynamic ocean management approaches to date.

Supplementing a view of dynamic ocean management as the practical enactment of a wet ontology, I read these approaches through recent work in geography developing Michel Foucault's (2008) incomplete articulation of an *environmental* mode of biopower; in particular, a strand interested in how the "naturalness of nature" (Braun 2014, 60) has become a means of government in the context of contemporary climate and biodiversity crises (discussed in section 5.1.3 in Chapter Two). Bruce Braun (2014, 58, original emphasis) has described the ways in which power in contemporary environmental governance increasingly operates through a "decidedly *fluid* and *flexible* landscape", in which the imperatives of modernist command and control give way, if in partial, incomplete ways, to the modulation of processes and flows (see also Anderson 2012; Barker 2015; Hinchliffe and Bingham 2008; Lorimer 2020). Wakefield and Braun (2019, 201) suggest that such approaches are widely appealing for offering "nature's very own solution to the volatility that our activities have introduced into global climate. Nature is there to assist us, provided that we understand what it is capable of doing." Paradoxically, perhaps, it is only through the development of large digital infrastructures and networks of sensors that the 'capabilities' of nature – in particular, continually mobile marine animals and shifting environmental conditions – become visible, allowing proponents of dynamic ocean management to view governing through the naturalness of nature as a distinctive new possibility.

In reading these approaches thus, I at once affirm that dynamic ocean management may represent a 'wet ontology' in practice, but also suggest that such analyses might be furthered by explicitly considering how power comes to operate through environments and animal bodies in these novel forms of ocean governance. In particular, while dynamic ocean management may inaugurate new possibilities for negotiating the requirements of various human and non-human actors co-existing in oceanic spaces, recent critical scholarship on data- and digital technology-driven approaches to environmental governance also points to a range of potentially negative, exploitative, and less equitable outcomes stemming from such approaches (Bakker and Ritts 2018; Nost and Goldstein 2021; Ritts and Simpson 2022; Sandbrook et al. 2021). Indeed, several scholars have noted that 'smart' approaches to environmental governance can lead to new relations between actors, human and nonhuman, but that they also often favour and reinforce already established socioeconomic and political projects (Bakker and Ritts 2018; Lehman 2020; Nost and Goldstein 2021). These concerns are taken up further as I elaborate on the Ocean Sentinel project and its potential implications – for albatrosses, fishers, and the relations between conservation and fisheries governance actors – in the following sections.

5.3. Ocean Sentinel

Ocean Sentinel is positioned in relation to two related but distinct ocean governance problems. First, the bycatch of albatrosses and other seabirds in commercial fisheries which, as I identified in the introduction and the previous chapter, has had disastrous implications for these birds as they become fatally entangled in fishing equipment whilst searching for food (see Dias et al. 2019); and, second, widespread illegal, unreported, and unregulated (IUU) fishing, which threatens national sovereignty (when IUU boats operate within nations' exclusive economic zones) and undermines international efforts to manage fisheries sustainably, producing an estimated annual catch of between 11 and 26 million tonnes of fish and severely impacting non-target species like seabirds (Agnew et al. 2009). In the following two sections, I Illustrate, first, the existing approaches to mapping overlaps between albatrosses and fishing activities in marine space and how the Ocean Sentinel project is positioned as a response to their deficiencies. Secondly, I move to consider how Ocean Sentinel then shifts from a scientific project interested in albatross-vessel interactions

towards one interested in the surveillance and control of IUU fishing and in so doing operationalises albatrosses for marine governance.

5.3.1. Mapping seabird-fishery overlaps

In 1997, the conservation NGO Birdlife International (hereafter BirdLife) established the Global Seabird Programme in response to fisheries-related declines in seabird populations worldwide and particularly to the declines of albatrosses in the Southern Hemisphere (see BirdLife International 2004a). One of the programme's early tasks was to identify the precise nature of seabird bycatch as a problem, by locating it geographically and identifying the actors responsible for addressing it. This involved the creation of new kinds of cartographic representations – distribution maps – which transformed existing seabird tracking data into an estimate of different species' ranges and 'hotspots' of habitat use where the birds spend the majority of their time (BirdLife International 2004b).[26] Such maps provide a basis for identifying *hotspots of risk,* areas where spatial overlaps between birds and fishing are greatest. Fishing effort data is typically provided by fisheries management organisations at a very coarse resolution (5x5^{o} grid squares) which means that albatross distribution data has to be resampled at this resolution, creating highly pixelated overlap maps where risk is equated with the co-occurrence of albatrosses and fishing activity in large, gridded ocean areas (Figure 8).

[26] Although new in this context, distribution maps have been an important output of wildlife telemetry since the 1980s, used to show how animal populations use space (Larkin and Halkin 1994; Gallerani Lawson and Rodgers 1997). Producing these maps involves transforming location data into an estimate of density, taking account of various population parameters. Early software was designed for terrestrial animals, and smaller sample sizes and areas. The approach was first modified to suit albatross tracking data in 2000 (Wood et al. 2000).

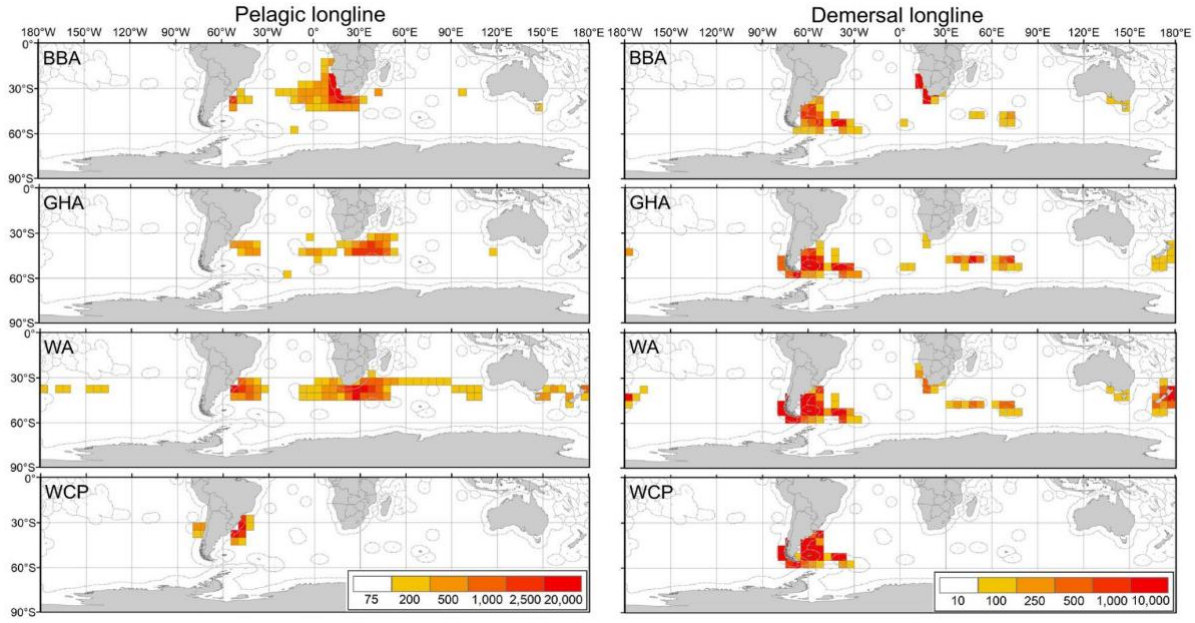

Figure 8 - Overlap between seabirds[27] and fishing effort, averaged 1990-2009. Reproduced from Clay et al. 2021 under a Creative Commons Attribution 4.0 International License. https://creativecommons.org/licenses/by/4.0/

These maps have consistently identified the areas beyond national jurisdiction, or the 'high seas,' as some of the most important at-sea areas used by albatrosses and petrels. They therefore implicate the regional fisheries management organisations (RFMOs) which manage fisheries in these areas as the primary actors responsible for addressing seabird bycatch (see Beal et al. 2021; Carneiro et al. 2020; Clay et al. 2019). RFMOs were established from the 1960s onwards as fora for international cooperation on high seas fisheries management issues in response to declining fish populations and catches. By the mid 1990s, further agreements, including the 1982 Law of the Sea Convention (UNCLOS), the UN FAO Code of Conduct for Responsible Fisheries (1995) and the UN Fish Stocks Agreement (1995), had cemented obligations for states to cooperate within RFMOs and a duty for RFMOs to conserve both the target and non-target species affected by fisheries (Small 2005; Swan 2004). However, in the early 2000s many RFMOs had not recognised seabird bycatch as an issue or placed it highly amongst their management priorities (see Dunn, Sullivan, and Small 2007). In the absence of reliable data about bycatch from RFMOs, the burden of proof fell largely on conservationists to demonstrate that seabird distributions overlap with the 'areas of competence' of each RFMO and that there is a relationship between this overlap and

[27] The seabird species included in the maps are: black-browed albatross (BBA); grey-headed albatross (GHA); wandering albatross (WA); and white-chinned petrel (WCP)

seabird population declines. As Anne, a seabird ecologist with the British Antarctic Survey, summarised:

> "you have to give [RFMOs] a lot of data before they will accept that it's a problem that they need to deal with. So that's where the tracking data is really helpful, because you can say 'Actually, we do know that the distribution of this particular species overlaps with your area of jurisdiction and this species is declining therefore we think it's likely bycatch in your area that's an issue.'" (interview, 12.02.2021)

There has been some recent debate around whether this tracking data, or the form it commonly takes when presented to RFMOs or in published research – distribution and overlap maps – sufficiently captures the 'real' nature of seabird-fishing vessel interactions and bycatch risk. To give one example, tracking data has tended to overrepresent the mobilities of adult breeding birds because they are easier to study with available technologies. These birds return frequently to their colonies to incubate and feed their chicks, where devices can be attached and removed at regular intervals, whilst juvenile and non-breeding birds often spend amounts of time at sea that exceed the battery lives and adhesive capacities of existing devices (Georgia, interview, 09.02.2021). However, albatrosses' mobilities are known to differ by life-history stage and, recent studies suggest, even according to individual birds' personalities (Weimerskirch et al. 2015; Patrick, Pinaud, and Weimerskirch 2017). As such, several ecologists and conservation practitioners explained to me, maps based on this tracking data can fail to capture hotspots of actual bycatch, making it difficult to advocate for conservation interventions in these areas. For instance, Georgia, a seabird ecologist from BirdLife, explained:

> "There were a lot of black-browed albatrosses dying [in the fisheries] in the coast of Brazil, but they were mostly juveniles and the problem is that until very recently we couldn't do anything about that, because we didn't have the tracks of any juvenile black-browed albatrosses […] we use the tracking data to go to RFMO meetings to identify priority sites and then we would go to the meetings and in our maps the birds were not actually on Brazil at all, even though we knew that a lot of birds were there, but this was because we weren't tracking juvenile birds" (interview, 09.02.2021).

Sandra, a bycatch programme manager with the RSPB, pointed to reports from Japanese fishers that they were catching juvenile grey-headed albatrosses in part of the Atlantic Ocean. This, she said:

> "was surprising because when we looked at the data we didn't really have them being in that area from the tracking data […] so then that led to tagging of juveniles and collecting a couple years of data and overlapping it with fishing effort data and from that we found out there actually was this new hotspot we didn't know about. So, the RFMO then knows there's this area where there's high risk of bycatch, and then in an ideal scenario it means measures will be more stringent." (interview, 24.02.2021)

In light of such examples of surprise or omission, practitioners are careful to stress that the maps they produce about bycatch risk, on which they base some of their advocacy work, "provide an estimate of potential, and not real, risk" (Clay et al. 2019, 1890). As critical scholarship in the social sciences and humanities has identified, however, animal tracking data and their representations risk presenting a minimal, simplified view of animals, ecologies, and human-animal interactions which can render certain forms of intervention possible whilst discounting others (Benson 2016a; Bergman 2005; Unnithan Kumar et al. 2022). In this instance, the dynamic mobilities of albatrosses in relation to marine ecologies and their own life-history stages, and their potential interactions with vessels, are spatiotemporally fixed in a way that renders it difficult to account for difference. This has been identified as a deficiency of the overlap mapping approach. Spatial overlap at the 5x5° grid square scale necessitated by existing fishing effort data may equate to very little *interaction*, or, by contrast, interactions may be occurring in areas of minimal large-scale overlap. Alexandre Corbeau and colleagues (2021, 695) have even suggested that analyses of bycatch risk made using 5x5° fishing effort data "do not correlate at all with time spent [by albatrosses] interacting with boats."

5.3.2. From overlaps to interactions

The Ocean Sentinel project was initially developed as a response to these approaches, which the researchers behind the project saw as "obviously insufficient to measure overlap and inform conservation measures" (Weimerskirch et al. 2018, 244). To bypass the coarse resolution fishing effort data provided by RFMOs, the researchers developed an alternative

approach which could detect the presence of fishing vessels independently and identify interactions as they occurred in real time. Whilst vessels can be detected in various ways – within Exclusive Economic Zones (EEZs) licensed vessels must submit location data via a vessel monitoring system (VMS) and vessels in the high seas use an equivalent automatic identification system (AIS) – these systems are not systematically used and the data can be difficult to access (Malarky and Lowell 2018; Weimerskirch et al. 2020). Radar systems, however, are reliably used by vessels for safety and navigation, creating a signal in the 9.41GHz X radar band which can be detected by antennae small enough to integrate into a bird-borne device. This fact was used by the researchers to develop loggers capable of sensing vessels regardless of whether they could access vessel location data, or whether the vessels were submitting this data at all. To validate their approach, the researchers negotiated access to VMS data from the French government agency responsible for monitoring the marine areas around where the albatrosses were nesting. They could thus see whether the devices they were using could detect the vessels identified through the VMS.

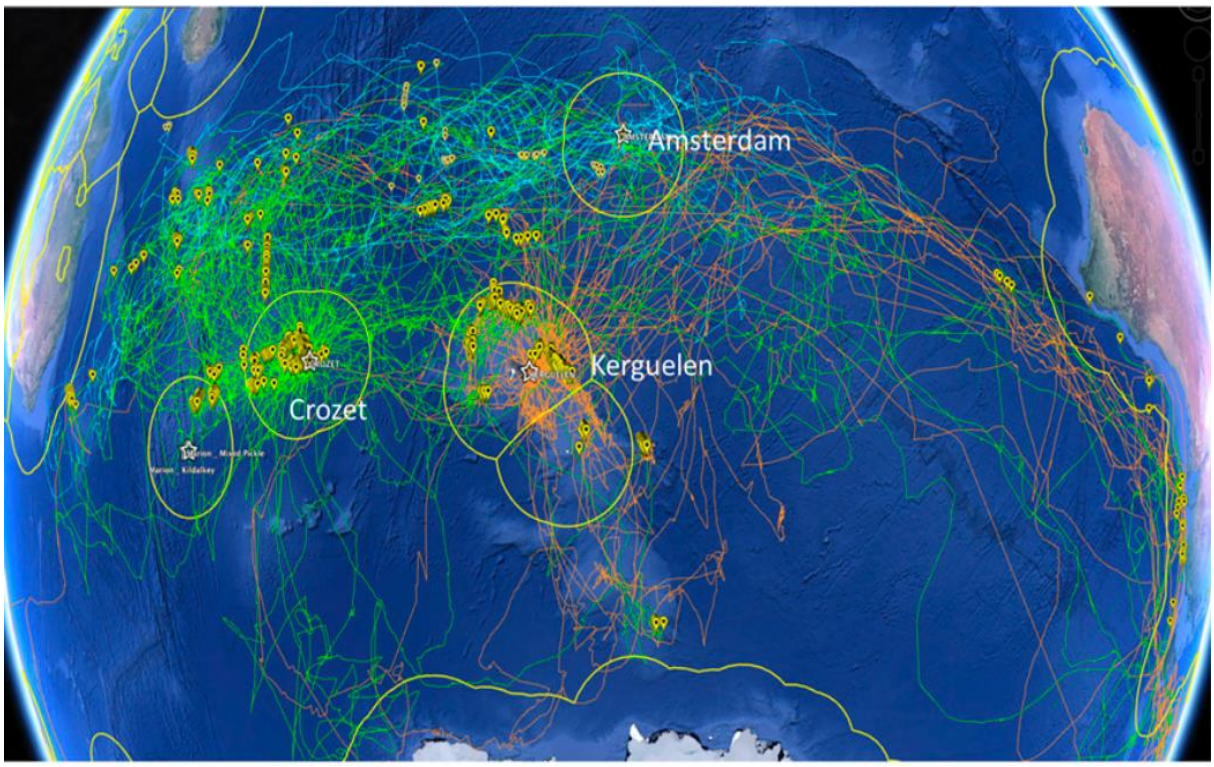

Figure 9 - Bird tracking and vessel location data collected by Ocean Sentinel's loggers. Lines show movement of individual birds from different colonies (orange from Kerguelen, green from Crozet, and blue from Amsterdam), yellow tags show radar detections, and yellow lines delineate exclusive economic zones. Source: Henri Weimerskirch. Reproduced with permission.

5.4. Operationalising seabirds for fisheries surveillance and control

As I outlined in the introduction, this approach morphed from a scientific project to better account for the interactions between albatrosses and fishing vessels to inform conservation efforts into a technique for fisheries surveillance when the researchers discovered discrepancies between the vessels they were detecting and this VMS data – suggesting the presence of undetected illegal fishing vessels. It was at this stage that the project both adopted the name 'Ocean Sentinel' and began to advocate for "the potential of using animals as Ocean Sentinels for *operational conservation* […and] improving remote surveillance of the oceans" (Weimerskirch et al. 2020, 3006 my emphasis). To achieve this, the researchers worked with the Terres Australes et Antarctiques Françaises (TAAF) – responsible for the administration of the French Southern and Antarctic Lands – and the Southern Indian Ocean Regional Operational Surveillance and Rescue Center (CROSS) – which coordinates search and rescue and fisheries control missions from Réunion to other French waters in the southern Indian Ocean – to develop a system they visualise in Figure 10 below.[28]

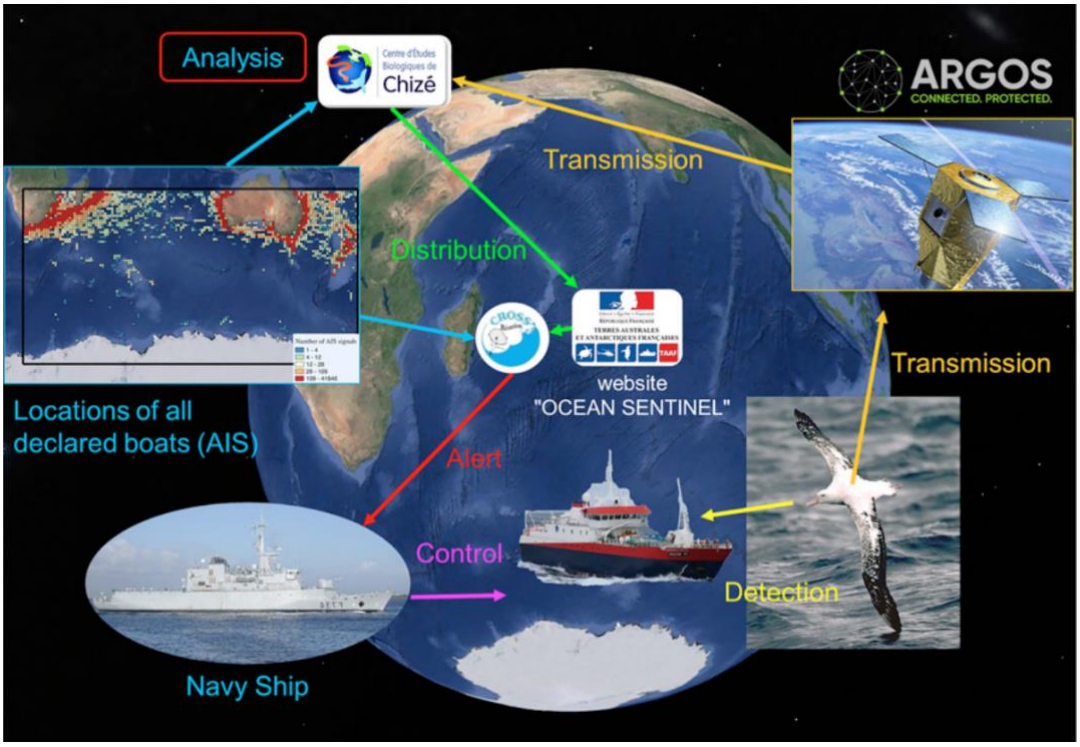

Figure 10 - A schematisation of the Ocean Sentinel project. Source: Henri Weimerskirch. Reproduced with permission.

[28] More information on the TAAF can be found at https://taaf.fr/; and more information on CROSS can be found at http://www.dm.sud-ocean-indien.developpement-durable.gouv.fr/cross-r24.html (last accessed: 15.03.23)

The purposes of this system are to identify illegal fishing activity in real-time together with albatrosses, transmit this information to enforcement agencies via the Argos satellite infrastructure, and to enable new forms of responsive fisheries control. Davide, a researcher on the project, explained how this works in practice:

> "[CROSS] cross-compare all their methods of surveillance, of which albatrosses are one, to the declared data. It occurred several times that we flashed a boat that was not declared by AIS in international waters but close to the national waters, close to the boundary, then they would start to get suspicious and make further inquiry and try to understand what this boat is and what it's doing here and they will send their boat if it's patrolling nearby." (interview, 26.08.2020)

By turning albatrosses into a 'method of surveillance,' Ocean Sentinel enacts an on-bird form of 'conservation surveillance', defined by geographers Chris Sandbrook and colleagues (Sandbrook, Luque-Lora, and Adams 2018, 2) as the "close watch kept over someone or something for conservation purposes." Whilst the project bears similarities to the dynamic ocean management approaches detailed in section 2 in terms of its aspirations towards real-time monitoring and responsive management and dissatisfaction with spatiotemporally fixed approaches like overlap maps, it is particularly in this respect that it differs from existing approaches. Where these other approaches combine data from animal-borne devices with data on human activities from other sources, Ocean Sentinel directly enrols albatrosses in conservation surveillance. I suggest this also differentiates the operation of power in Ocean Sentinel from those discussed in section 2. Rather than attempting to manage desired circulations within an environment in a flexible way, the on-bird surveillance developed by Ocean Sentinel might be seen to exemplify an emerging form of 'cyborg anatamo-politics' which Maan Barua (2021, 15) suggests is "reorienting animal bodies into technologies for dealing with shocks and turbulence." This is clearly expressed by Henri Weimerskirch's (in Roy 2020, n.p.) description of the birds in an interview with *The Guardian* as "like drones, only intelligent."

This framing places the project and its use of albatrosses in alignment with a growing number of conservation projects using drones and other digital monitoring technologies to achieve their objectives. Social scientists have noted that whilst such technologies open exciting new avenues for detecting illegal activities, protecting communal land-rights from

extractive industries, and monitoring biodiversity in remote and inaccessible areas, they may also "amplify existing dynamics of fear, mistrust, or conflict" and be used to inaugurate "undesirable new forms of control" (Millner et al. 2023, 4–5; see also Humle et al. 2014; Sandbrook 2015; Sandbrook et al. 2021). Francis Massé (2018, 56), for example, argues that by using drones "conservation-security actors are increasingly going aerial to mobilise the vertical as a dimension of space and power to protect wildlife, neutralise those who threaten them, and ultimately secure conservation areas below." Albatrosses, understood in relation to these practices, become aerial technologies for enacting security. The researchers I interviewed from the project distinguished, for instance, between undeclared vessels detected in international waters – which were merely interesting to know about – and those in or near French national waters which would trigger a response from CROSS ("if the detection happens in the middle of the Pacific Ocean, then it's not their problem," Davide, interview, 26.08.2020). The project thus participates in the maintenance and policing of boundaries demarcating different kinds of ocean space; the affiliation with French government agencies renders Ocean Sentinel as much about conservation as about policing incursions of illegal fishers into French national waters.

5.4.1. Albatrosses as a natural solution

Ocean Sentinel retains aspects of the aspirations to govern through the 'naturalness of nature' outlined in section 2, making the comparison to drones (even with an 'intelligent' caveat) insufficient to understand what is at play here. As a 'natural' governance solution, albatrosses seemingly offer a way to render visible and police in real-time a set of activities – IUU fishing – thriving on the invisibility afforded to them by the high seas. It is their specific, sentient and lively qualities that qualify albatrosses as "new beasts of burden" (Barua 2021, 13) for performing surveillance work. These qualities, rather than their resemblance to technological machines, are essential to detecting vessels in hitherto impossible ways – offering the "first estimate of the extent of nondeclared fishing" in the area surveilled (Weimerskirch et al. 2020, 3006). For instance, whilst more powerful radar-based techniques for detecting vessels exist, these are costly, offer limited, unselective coverage of ocean areas, and have not been widely used (see Kroodsma et al. 2022). Albatrosses' own vast ranges and attraction to vessels in search of food are seen to overcome issues of range and

unselective coverage in a cost-effective way, by bringing small, low-cost radar-detecting devices easily within detection range of fishing vessels (Weimerskirch et al. 2020). As Michel, a project member, explained:

> "we worked on wandering and Amsterdam albatrosses because there were conservation issues and because they were large and we know them quite well, and they are attracted by vessels so in fact it was a good combination, and they are foraging very far, 2-3000km from the colony and the juveniles disperse across the whole Indian Ocean, so they are very good sentinels." (interview, 01.03.2021)

However, by the same token, using the birds in this way requires working *with* them – they cannot be directed like a drone, and whilst they extend human ocean sensing capacities in new ways, this is mediated through their own proclivities. In contrast to visions of drones associated with aspirations of totalising surveillance and control (see e.g. Gregory 2011), the more-than-human mode of surveillance mobilised here is highly contingent on the decision-making processes and motivations of the birds it deploys. As Davide explained:

> "with the adults when they are breeding they make round trips from the island where they breed so in a way they are constrained where they go and are staying around the colony. So around the Isle of Crozet there is a shelf and when the chick has hatched it's really more rare that they go beyond this shelf. So, they go in international waters mainly during the incubation phase. So, that's one thing for the Crozet birds depending on where they are in their breeding phase it will determine where they go, where they patrol, so from a sentinel point of view if your aim is to reinforce surveillance within the national waters then you can of course track them anytime you want but if the aim is to locate non-declared vessels in international waters then you will have to just restrict yourself to the incubation period of the birds […] And then you have the motivation of the birds, so whether they want to approach the boat or not depending on which type of boat it is, whether the boat is actually fishing at this time or not. This could make a difference as well." (interview, 26.08.20)

5.4.2. Operational sentinels, or the albatross cop

This operational rendering of animal sentinels as agents of surveillance is closer to the term's original meaning of a border guard, vigilant for hostile incursions, than to how it is frequently used by ecologists to describe species which provide early warning of environmental change. Arthur, a seabird ecologist with the British Antarctic Survey, even suggested that "Henri

[Weimerskirch]'s idea is using them as proper sentinels, I use the word sentinel but it's not really properly right, he's using the birds almost as a policeman really. That is the appropriate use of sentinel in fact because you're following up the spy in the sky with a fisheries patrol vessel" (interview, 26.03.2021). Indeed, the 'policeman' or 'albatross cop' was a figure enthusiastically embraced by media coverage of Ocean Sentinel. *The Guardian*, for example, wrote "Albatross cops may soon be taking to the skies [...] to scan remote parts of the Pacific Ocean for illegal fishing boats" (Roy 2020, n.p.). *The New York Times* said of these illegal vessels, "They're stealthy at sea, but they can't hide from the albatross" (Kornei 2020). Through association with powerful framings of the ocean, and particularly the high seas, as spaces of lawlessness and criminality (noted in the Introduction), Ocean Sentinel received significant wider attention in a way that other tracking studies and the problem of seabird bycatch alone have not. Coverage reframed albatrosses not simply as victims of fishing malpractice but as surveillance agents uniquely positioned to illuminate illegal fishing activities which threaten them and their wider marine ecologies. Researchers on the project actively promoted this reframing. Samantha Patrick (2020, n.p.), another researcher on the Ocean Sentinel project, wrote in *The Conversation*, for instance, that projects like Ocean Sentinel can empower animals to "collect the data needed for their own conservation."

5.5. Specifying the implications of on-bird surveillance

Similar ideas have been gaining traction beyond Ocean Sentinel amongst other projects also attracted to the characteristics of specific animals that commend them for (conservation) surveillance applications. Albeit not always informing fisheries enforcement, the method of using birds to monitor fisheries (and seabird interactions, rather than overlaps, with them) has been taken up in South Georgia, Aotearoa New Zealand, Japan, and the Mediterranean (BAS 2019; Grémillet et al. 2019; Nishizawa et al. 2021; Weimerskirch et al. 2020). In southern Africa, sentinel animals have been used in poacher early warning systems which deploy "an internet-of-things architecture with wearable sensors, wireless data transmission and machine learning algorithms" (de Knegt et al. 2021, 1) to sense prey animal behavioural signatures that indicate the presence and location of poachers within protected areas. Elsewhere, the bodies and affordances of animals are being actively harnessed for the purposes of national security (Kosek 2010). As such approaches proliferate, they raise new

questions for geographers interested in conservation surveillance and transformations in environmental governance, and also for conservation practitioners. In particular, as the agencies of living, sentient beings are operationalised towards governance objectives, what are the consequences for the individual animals themselves?

5.5.1. On-bird risks

The albatross cop is a generative figure for thinking through some of these implications. Indeed, there are important ways in which this figure is an inappropriate and even dangerous one for albatrosses, and in which the relations of power at play place them in positions of heightened vulnerability rather than authority. Considerations relating to the implications of instrumenting individual animals for conservation science have concerned conservationists since the outset of their use (Boitani and Fuller 2000; Horning et al. 2019; Wilson, Grant, and Duffy 1986). Seabird researchers have focused on the potentially negative effects of devices on their wearers, in terms of weight, potential irritation and effects on aerodynamism and foraging effectiveness(Phillips, Xavier, and Croxall 2003; Vandenabeele et al. 2012; Wilson et al. 2002). However, by enrolling their wearers in novel forms of conservation surveillance, these devices now expose animals to potential harms beyond their direct physical effects. In other contexts, researchers have noted the vandalism, destruction, or theft of technologies like camera traps by people who object to being observed by them without prior consultation or consent (Mathur 2021; Simlai 2021). In Malta, where bird conservation has become increasingly militarised, hunters have deliberately shot protected species in active defiance of conservationists (B. Campbell and Veríssimo 2015). As such, when animals become bodily implicated in surveillance regimes, resistance to these regimes may result not only in the destruction of technologies but also violence towards animals (see Cooke et al. 2017). As such, on-bird surveillance inaugurates new on-bird risks that may multiply, rather than address, the existing risks posed to birds by fishing activities.

In several interviews, conservationists commenting on Ocean Sentinel suggested that the greatest of these risks was that albatrosses would be shot by fishers associating them with surveillance and recriminations. Arthur, the ecologist from the British Antarctic Survey, had recently been involved in a project which used similar location-radar devices to Ocean

Sentinel but expressed to me his strong reservations about using them to pursue the same kind of approach:

> "We decided not to do that at the outset. I was nervous about IUU vessels having small arms on board and actually shooting albatrosses and that's come up quite a few times in discussions. Wanderers[29] as well are so easy to spot, there's not that many of them and the same birds probably stay behind the vessels for could be hours on end whereas black-brows there's so many of them that you wouldn't easily tell which had a logger on it and which didn't. Henri [Weimerskirch] says apparently that he thinks that that's not an issue, he's not had any birds with the radar devices going missing. One disappeared but I think the device might have fallen off or something. But I actually kept away from the idea or didn't even start off on the idea that we would be doing a 'spies in the sky' sort of thing on an active basis where the patrol vessels would then follow up. It was all about the science of the interactions, not the enforcement [...] So for all these reasons I just never…It's an ok idea, if it's safe then I can accept it's a clever idea, but I just didn't do it" (interview, 10.09.2020).

While Arthur suggests fishers may attempt to discriminate between birds with and without loggers, Alison, a conservationist working with BirdLife's Albatross Task Force programme, suggests Ocean Sentinel may blur the distinctions between albatross and surveillance technology in more general ways, such that the possibility of on-bird surveillance is sufficient motivation for fishers to shoot albatrosses:

> "The first time I read about [Ocean Sentinel] I said this screams at me, red flags, red flags everywhere. Why is Henri [Weimerskirch] doing that? I don't know. I heard him present it the first time at a conference in Barcelona in 2016, he showed this albatross doing little dots and it sounded amazing and then he said 'Oh, it could be used like this', and the hands went up and it was like, no, all that's going to do is put a red target dot on albatrosses and whenever a fisherman sees an albatross they're going to take a shotgun and shoot it, because it might be monitoring them" (interview, 03.02.2021).

For Alison, the risk to birds may increase substantially in step with their association with surveillance. This, for her, undermines a long history of more positive relations between fishers and albatrosses, in which the birds signalled the presence of fish or provided companionship and distraction on long voyages, which may be a key source of goodwill for

[29] Wanderers refers to the wandering albatross species.

tackling bycatch through collaborative approaches with fishers (see also Barwell 2013). Given the relative recency of Ocean Sentinel and limited take-up of the approach thus far, such concerns are currently speculative. However, they complicate the narrative that Ocean Sentinel equips albatrosses to contribute to their own conservation, raising important and enduring biopolitical questions concerning the wellbeing of individual animals relative to their populations in conservation practice. As Krithika Srinivasan (2014, 501) notes, conservation involves a complex "entanglement of harm and care" in which individual animals' lives are often subjugated by biopolitical techniques intended to benefit the collective. Here, the reframing of encounters between birds and vessels not only as sites of highly unequal risk, vulnerability, and death but also as sources of potentiality and data for governance points to the ways in which birds are not only instrumented, but also become instrumental and, possibly, expendable.

5.5.2. Naturalising surveillance

Emerging regimes of digital ocean governance also raise a wider set of concerns that relate not to how surveillance operates through nature and thus inaugurates new potential risks to nonhuman animals, but rather to how it becomes naturalised as a solution to marine ecological crises, painting these as problems of insufficient data or oversight. There is, to be sure, little doubt that the opacity of the high seas is concerning from the perspectives of regulation and flourishing marine ecosystems. However, new initiatives like Ocean Sentinel raise troubling questions over who benefits from addressing these problems and whether they are, or should be, addressed at the expense of the privacy and livelihood concerns of resource users or primarily via control compared with more collaborative approaches (Bakker and Ritts 2018; Drakopulos, Havice, and Campbell 2022; Drakopulos et al. 2022). Indeed, whilst Ocean Sentinel promises to bring researchers and regulators closer to the activities of fishers by rendering their activities visible in new ways, it increases the *relational* distance between these different actors and ignores the more structural drivers of a problem like illegal fishing that might be addressed in many alternative ways.

Ecologists and conservationists that I interviewed expressed concerns that by pursuing surveillance and enforcement, projects like Ocean Sentinel might undermine the

relations they have spent decades building with fishers and within RFMOs. For them, addressing albatross bycatch in fisheries or, more generally, reforming fisheries towards more sustainable practices is fundamentally *not* a question of enforcement and control. Operating from a position of limited power within fisheries management organisations, good relations have been vital to what conservation NGOs have been able to achieve in these organisations and in working directly with fishers.[30] Whilst, ostensibly, Ocean Sentinel targets illegal fishing activities and not the operation of fisheries within the remit of RFMOs, it still takes place within the context of seabird conservation activities in general and concerns some conservationists for its ambivalence towards or rejection of the approaches they have taken. Georgia (interview, 09.02.2021), who also worked on a project using similar devices as Ocean Sentinel which rejected an enforcement component, told me, "It is very hard to build a relationship when you go to these RFMO meetings so I think if you go for enforcement the relationship that we built for years will break. So, I think we need to be quite careful here." Alison (interview, 03.02.2021), moreover, suggested that to achieve change in fisheries, "it's years of work. It's years of engagement and trying not to burn bridges and make as many as possible, and just keeping at it and not using the stick too many times. And it's going out there [on boats] and showing that you care. That's really the recipe." In reference to the alternative approach taken by Ocean Sentinel, she stated "I'm completely against that approach. To me that's because you just sit behind your computer and don't go out with the fishermen" (ibid).

5.5.3. Practicability

We might also problematise the ambitions of Ocean Sentinel in a way which calls into question its wider practicability. Whilst enhancing ocean surveillance capacities through new digital approaches *is* becoming an increasingly common normative ambition amongst ocean governance actors (see Drakopulos, Havice, and Campbell 2022), the capacity to marry these ambitions with more effective forms of governance in practice is still constrained by such factors as patrol vessel numbers, the absence of appropriate legal and regulatory

[30] In addition to featuring in several interviews, this theme was prevalent in a bycatch session of the World Seabird Conference (2021), and is supported further by BirdLife's Albatross Task Force and its efforts to work collaboratively with fishers to develop solutions to seabird bycatch in fisheries.

frameworks, and resistance from marine resource users and policymakers. As proponents of dynamic ocean management approaches have observed, there are a host of technical, legal, political, and social obstacles to be overcome before real-time, responsive modes of ocean governance can become more widespread (see Hobday et al. 2014). Whilst 'albatross cops' make for appealing news headlines, perhaps, of all the approaches in development, those which pose identifiable risks to the individual animals enrolled will be the least likely to scale, particularly if they face resistance from the communities of conservation practitioners they operate adjacently to. In conclusion, I highlight a further set of developments in research and practice which will allow for the better conceptualisation and shaping of such emergent approaches.

5.6. Conclusion

The surveillance of animals, often enabling forms of biopolitical control, has been much discussed by more-than-human geographers and others in related fields (Bergman 2005; Benson 2010; Blair 2019; Whitney 2014). Whilst a growing literature has charted the emergence of conservation surveillance regimes and the technologies which underpin them, little attention has been paid to the ways in which ecological monitoring and surveillance are achieved with animals and animal-borne devices. Sandbrook and colleagues (2021, 1) suggest that telemetry devices and by extension the animals that wear them are not a conservation surveillance technology because, unlike technologies like camera traps and drones, they do not collect data on "peoples' spatial and temporal activities". I have suggested that several recent examples demonstrate to the contrary. Many ecologists are actively reaching and embracing a "transformational point" at which they move from simply studying animals towards assembling a Big Data ecology that views animals as "naturally evolved sensors of environments …[that] help us monitor the planet in completely new ways", including human activities (Kays et al. 2015, 1222). However, as I outlined in Chapter Two and in section 5.2 of this chapter, sensors, or relatedly drones, are insufficient figures with which to understand these dynamics. Sentinels, and more specifically *operational* sentinels, capture the productive tensions between framings of animals as technologies and as agents in extended more-than-human networks of surveillance which create opportunities for new forms of environmental governance.

This chapter has charted the changing ways in which telemetry and biologging technologies contribute to the governance of fishing activities, including but not limited to albatross bycatch. I have discussed the dominant approach, the mapping of overlaps between bird distributions and fishing activity creation of overlap maps as an advocacy tool, as one which minimises animals, ecologies, and human-animal relations in ways that some researchers and conservation practitioners view as deficient. To address this deficiency, the Ocean Sentinel project has initiated a new way of using albatrosses to inform conservation practice. This on-bird surveillance bears similarities to an emerging suite of dynamic ocean management approaches which seek to govern through marine ecologies in new, responsive ways, but differs in its mobilisation of a 'cyborg anatamo-politics' which turns albatrosses into surveillance technologies or framed differently, into operational sentinels captured by the media-friendly figure of the 'albatross cop.' I discussed the implications of this, and other similar approaches in development, in terms of the risks posed to the individual animals enrolled, the naturalisation of surveillance and control as an appropriate and necessary solution to environmental problems, and in terms of wider practicability.

As on-bird surveillance and similar techniques develop, I argue there is a need for three developments in research and practice. The first is a need for ethnographic research on fishers' experiences of surveillance (by bird and otherwise) and of their day-to-day relations with animals more generally. The experiences of on-board observers who spend significant time observing these relations may also be helpful here. These insights would be vital to further developing, or perhaps fundamentally challenging, these emerging techniques. Moreover, they would extend important early social scientific analyses of dynamic ocean management (Bakker 2022; Bear 2017; Peters 2020) by addressing the perspectives of marine resource users. Secondly, in the same way that the research community has established and debated guidelines related to the weight and attachment of telemetry devices (Richard A Phillips, Xavier, and Croxall 2003; Vandenabeele et al. 2012) there is a need to establish context-specific ethical and regulatory frameworks that consider what might constitute an acceptable level of risk to individual animals employed in conservation surveillance work, weighed up against potential benefits to their populations or wider ecologies. Researchers have highlighted that the evolution of digital approaches to

environmental governance often outpaces the careful consideration of their implications, and I follow others in arguing the need for clear principles for the responsible use of conservation surveillance technologies (including animals) (Sandbrook et al. 2021).

The third development relates to an analytical framework for considering wildlife tracking in critical animal research. Whilst I caution against accounts that imply biologging and telemetry could not be used for surveillance, there is equally a need to avoid framing projects like Ocean Sentinel as part of an inevitable trajectory in wildlife tracking towards forms of conservation surveillance and biopolitical control. Nustad and Swanson (2021) diagnose such framings as the "Foucault effect" in environmental governance scholarship. By this they mean that a particular orientation towards the relationships between scientific projects, ecological management, and state control informed by the works of Michel Foucault may forecloses on perceiving other modes of socioecological relations. In contrast to this, Kristoffer Whitney (2014) offers a more affirmative reading of the insights and affective intimacy telemetry offers into animals' lifeworlds, one which is also expressed in Adam Nicolson's (2017) creative non-fiction account of seabirds' lives which draws substantially on tracking research, and Thom van Dooren's (2014) 'albatross stories' (discussed in the following chapter). Whilst such readings may not be appropriate to Ocean Sentinel specifically, clearly the kinds of technologies the project uses may also offer us ways of knowing and protecting these birds flying near the edge of extinction that are not reducible to surveillance or control. In the face of increasing securitisation and militarisation in conservation practice, I suggest retaining these more open perspectives towards digital ways of knowing animals offers an important corrective.

Chapter Six

“Spirits of the seas”

Understanding sentinels through sentiment

6.1. Introduction

In 2004, the UK-based charity The Conservation Foundation and the Tasmanian government partnered with British betting company Ladbrokes to raise money for albatross research and conservation through a 'Big Bird Race.' Millions of online gamblers were able to bet on the migration of 18 satellite-tagged juvenile shy albatrosses as they travelled from Tasmania to South Africa. Drawing parallels with horse racing, the satellite tags were referred to as 'jockeys', researchers as 'trainers', and island colonies as 'stables' (see Benson 2010). Each bird was assigned a name, like Ocean Spirit and Ancient Mariner, and a celebrity owner-cum-sponsor, including David Attenborough, singer Olivia Newton-John, and long-distance sailor Ellen MacArthur. Spectators and betters were able to track the birds' progress online, and bets could be taken on fastest average speed, the first to reach 'checkpoints' along the migration, and the 'winner' overall. The event was hugely popular; bringing in a five-figure sum within its first few days for the Save the Albatross campaign organised by BirdLife International (Llanos 2004). In the event's second year, a tragic development saw all 17 'competing' albatrosses die or disappear during their migration, dimming the prospects for a repeat event whilst poignantly highlighting the threats faced by the birds at sea (see Doughty and Carmichael 2011).

Conservationists, writers, artists, and public figures have expended considerable effort in positioning albatrosses – through diverse and sometimes strange initiatives like the one above – as what seabird conservationist and scientist John Croxall terms "the symbol and the spirit of the status of the global marine system" (1997, in Benson 2010). None of this is incidental to how these birds act as sentinels, but an integral part of it. While the previous chapter illustrated how albatrosses are operationalised for marine surveillance, my intention in this chapter is to broaden engagements with animal sentinels by drawing attention to a different way in which they are operationalised to communicate signals of environmental changes; namely, through sentiment. To capture how seabirds act as sentinels in this way, I develop the concept of 'sentinels of sentiment.' As I discussed in section 5.1.1 of Chapter Two, this concept emphasises the role of sentiment – broadly defined here in terms of the affects, emotions, and feelings that move people to care about nonhuman life – in the signalling done by sentinel animals, operating alongside scientific, reason-based dimensions.

It is informed by a view that affect – as it is variously defined – is crucial to understandings of the contemporary operations of power and politics (see B. Anderson 2016; Carter and McCormack 2006; Massumi 2002; McCormack 2003; Thrift 2004), including in conservation practice (see Barua 2016; J. Lorimer 2007). I mobilise the concept of sentinels of sentiment here to answer the research question: *"how do sentiments shape how seabirds act as sentinels?"*

Seabird ecologists Amélie Lescroël and colleagues' (2016, 213) definition of seabirds as 'ocean sentinels,' which understands "seabirds both as indicators of marine ecosystem health and as ambassadors of less visible, and often less charismatic, marine species, to improve […] global ocean conservation," offers a good example of the concept of sentinels of sentiment in use. This captures the systems of knowledge production I have described in previous chapters and the status of some seabirds, like albatrosses, as charismatic flagship species which move people sentimentally, morally, financially, or otherwise to respond to environmental issues (see Barua 2016; Collard and Dempsey 2013; Haraway 2008). Unlike other familiar terrestrial flagship species like bears and big cats, albatrosses' geographies can nevertheless make it challenging to assemble regimes of care around them based on affective, embodied encounters. We cannot visit an albatross in a zoo and there are few accessible opportunities for albatross-based tourism. In lieu of direct encounters with albatrosses, mediations of the birds in/as stories, photography, moving imagery, and interactive GPS visualisations are essential to cultivating care about them. I use care *about* instead of care *for* here because at stake are efforts to foster affective and ethical *dispositions* of care whose functions are to motivate or inform political interventions in the interests of nonhuman lives, rather than the "maintenance or concrete work involved in actualizing care" (Puig de la Bellacasa 2017, 4; see Roe and Greenhough 2023).

In this chapter, I trace the relationships between albatrosses and sentiments across three popular 'albatross stories' of the early 21st Century (see Van Dooren 2014). After a brief but important orientation towards albatross affordances and encounters, I begin by following a British long-distance sailing yacht, the 'English Rose VI', as its crew attempted to 'save the albatross' in the early 2000s, before the focus broadens to wider albatross conservation campaigns during this period. I then turn to examine photographer Chris Jordan's (2009)

photography series, 'Midway: Message from the Gyre.' These disturbing images of dead albatrosses with stomachs full of plastic objects are partly credited with raising public awareness of oceanic plastic pollution and catalysing international remedial action. Finally, I turn to a very different kind of imagery and sentiment, highlighting the New Zealand Department of Conservation's Royal Albatross webcam and the RSPB's Albatross Stories social media campaign as prominent examples of the significance of 'cuddly charisma' in albatross conservation. While these are not the only albatross representations that I might draw from to narrate this account,[31] they are a set of high-profile ones amongst the predominantly Western audiences targeted by conservationists, chosen from a review of relevant materials (as outlined in Chapter Three) to illustrate consistencies and variations in albatross sentiments and to develop the concept of sentinels of sentiment for wider scholarly use.

The sentiments I specifically draw attention to are captured by the utterances *awe* (awe-some)*, eww* (awful), and *aww* (endearing). This framing is inspired by Jessica Maddox's (2022) ethnography of animals in digital cultures, which explores the entanglement of internet *aww* and internet *eww* – cute aesthetics and affects, alongside those that are disturbing, harmful, and 'toxic'. To this I add *awe,* a third important 'affective logic' (e.g. Carter and McCormack 2006) at work in mediated human-albatross encounters. These implicate different kinds of animal bodies, operate through different media and spaces of encounter (from corporeal to screen-based encounters), and act towards different, although interrelated, ends. This typology develops existing work that has parsed the different affective logics and political economies at play in charismatic animal imagery (e.g. J. Lorimer 2010; Turnbull, Searle, and Adams 2020). As this work illustrates, such affective logics are rarely entirely distinct; they are often put to work simultaneously and interact with one another. I show how awe, eww, and aww each help make sense of distinctive but interlinked politics associated with albatrosses, their mediated circulations, and their conservation, and reflect in conclusion on how sentiments contribute to configuring the agencies of sentinel animals in environmental governance.

[31] For a detailed and wide-ranging account of the cultural history and associations of albatrosses, see Barwell 2013

6.2. Affordances and encounters

> "Every creature, as it 'issues forth' and trails behind, moves in its characteristic way." (Ingold 2011, 72)

Sentiments flow from (mediated) encounters between bodies and these encounters have both specific histories and geographies, and shape and are shaped by the affordances of encountering bodies (see Greenhough 2011; H. F. Wilson 2017). Albatrosses can move people to feel awe and wonder towards their lifeways, but it can be harder to feel these same things towards a pond beetle, for example. Drawing on James Gibson and Tim Ingold, Jamie Lorimer (2007, 914) describes affordances as "the inherent, ecological characteristics of a nonhuman in relation to the phenomenological apparatus of the body (human or nonhuman) that encounters and perceives them." In the Introduction I discussed the affordances of seabirds and albatrosses; here, I briefly reiterate those which are most significant to the sentiments described in the following sections.

Albatrosses exhibit some morphological, behavioural, and ecological differences across the 22 recognised species and, indeed, between individuals (e.g. S. C. Patrick, Charmantier, and Weimerskirch 2013). However, across these differences, we can distil some key shared affordances which configure the appeal of albatrosses to people. Albatrosses are some of the largest flying birds, weighing up to 10kg and with wingspans over 3 metres in some species, and long-lived. They are also extremely mobile, travelling hundreds or thousands of kilometres in single foraging trips. Their juvenile phase is long, often several years, and thereafter they often partner for life, rearing a single chick every year or two years. The birds' courtship displays are carefully sequenced and elaborate, involving rapid head movements, vocalisations, wing-spreading and delicate footwork. There is a certain beauty to these displays, which have been a focus of many natural history documentaries.[32] Albatrosses are also diurnal and tend to nest on open grassy or bare ground on (historically) predator-free islands. As such, they do not exhibit predator avoidance behaviours, making them easy to approach. Some of these affordances intersect more easily with those of

[32] For example, those produced by the BBC Natural History Unit (the Blue Planet and Frozen Planet series), National Geographic, and American photographer Chris Jordan's 'Albatross' documentary.

humans compared with, for example, smaller, nocturnal, and/or burrow-nesting species of seabird like certain shearwaters and petrels.

Albatrosses, then, are "big like us" (Hird 2009), their superlative characteristics (large size, mobilities, long lives) are alluring to people and combine to differentiate them from other seabirds, their temporal rhythms intersect with those of humans, and they express recognisable affection and care (or behaviours that can be interpreted thus) towards each other. These affordances configure their abilities to act as sentinels of sentiment. Three crucial caveats to this are that, first, albatrosses retain a distinct 'otherness' to humans. Their avian anatomies and extreme mobilities, to give two examples, are somewhat 'awkward' (e.g. Ginn, Beisel, and Barua 2014), difficult to relate with, and are not easily subsumed into neat aesthetic categories. Secondly, as we saw in Chapter Four, albatrosses' geographies make corporeal proximity with these birds difficult, as they overlap minimally with the space-times of much human activity. This privileges certain spaces of encounter, like on boats, at sea, and the screen, which influence the sentiments that are evoked by and with albatrosses. Their detectability is thus configured by histories that have created proximity between *some* humans and albatrosses, and by digital technologies that aid in sensing their worlds remotely. Lastly, encounters are *risky* and *unpredictable* – this is precisely what lends them their transformative potential. Derek McCormack (2003, 491), for instance, has written about of potentials for encounters between bodies to generate "transformation in awareness, thinking, feeling and relating" as a factor of their unpredictability (see also Barua 2016; Haraway 2008; H. F. Wilson 2019 on multispecies encounters). We cannot state, then, with any certainty what the relations between affordances, encounters, sentiments, and environmental outcomes *are*, only trace these as they emerge in particular instances. Tracing such instances is the task of the following sections.

6.3. Albatross Stories

6.3.1. The awe-some albatross

On a downbeat, sullen day in July, 2003, the yacht 'English Rose VI' sailed out of Ardmore on the Northwest coast of Scotland. Crewed by sailors John and Marie Christine Ridgway, Nick

Grainger, and Scott Simpson, the yacht was departing on a journey that would last 327 days and take in Cape Town, the Kerguelen Islands, Melbourne, Wellington, the Falkland Islands, and, finally, after some 28,000 miles, Tower Bridge in London in June, 2004. Once past South Africa, the *Save the Albatross Voyage*, as the crew's self-funded journey was named, would trace the circumpolar travels of wandering albatrosses to raise the profile of albatross conservation and draw attention to the threats faced by these birds at sea from longlining vessels.

John Ridgway, known for rowing the North Atlantic in 1966 with fellow British Army paratrooper Chay Blyth, and two previous round-the-world voyages in the English Rose, had become enamoured with albatrosses through encounters with the birds during his oceanic travels. "Many's the time on a lonely watch it's just been me and the albatross. It's the spirit of life, really. If we make them extinct, after millions of years, during our lifetime, what luck awaits the hapless human race, I wonder?" Ridgway mused in a BBC interview (Kirby 2003, n.p.). Tracing the travels of albatrosses, the voyage was also intended to facilitate the global travel of a strong albatross conservation message across diverse sites and publics. The crew met with politicians, conservationists, and public figures at stop off points, broadcasted daily updates via a BBC-hosted blog, and solicited signatures to a BirdLife International 'Save the Albatross' petition calling for stricter fishing regulations and enforcement and ratification of agreements to protect albatrosses and other marine life. The petition, which was part of a larger Save the Albatross campaign coordinated by BirdLife International and the RSPB, gained over 100,000 signatures - a symbolic target number intended to signify an equivalent number of albatrosses dying in fisheries each year - and was delivered by John and Marie Christine Ridgway to a fisheries meeting of the UN Food and Agriculture Organisation in Rome at the end of their voyage.[33]

In a reception marking the end of the voyage, a letter was read out from then-Prince Charles, whose interest in the voyage was part of his publicly staged patronage of albatross conservation in the 2000s (e.g. Doughty 2010). Prince Charles articulated his concerns in both a sentimental personal register – observing that "if they go it would be as if one's heart was

[33] See http://www.eurocbc.org/albatross_petition_nz_20jun2004page1700.html (last accessed: 19.06.23)

torn out" during a 2005 visit to the Taiaroa Head Royal Albatross Centre in Aotearoa New Zealand, officially opened by his sister Princess Anne in 1989 – and in ways which made them stand symbolically for a wider cause (Cooper 2022). For a fundraising dinner for the Albatross Task Force in 2005, the prince announced that "the albatross may be the ultimate test of whether or not, as a species ourselves, we are serious about conservation: capable of co-existing on this planet with other species" (NZ Herald 2005).His words closely mirrored those of John Croxall, then Chairman of the RSPB, who had recently written of albatross conservation efforts: "If we fail, this will not just prejudice the survival of magnificent albatrosses – truly the spirits of the seas. We will have failed to work internationally to safeguard the world's greatest global commons – the oceans" (2000, n.p., cited in Dunn, Sullivan, and Small 2007).

The Save the Albatross voyage supported a key period in the development of international albatross conservation campaigns, during which the focus has been said to move "from identifying problems to implementing policy" (Dunn, Sullivan, and Small 2007, 165). This period also cemented 'the albatross,' generically speaking, as the flagship for a wider set of seabird conservation efforts. Reflecting on the naming of the Albatross Task Force, rather than names like the Seabird Task Force or Albatross and Petrel Task Force which would describe the broader focus of the initiative's work, Alison, a regional coordinator for the Albatross Task Force, elaborated "it's about addressing the most, I wouldn't even say most important [species], just the one that you can get funding for and is more charismatic and that you can actually draw some focus to. Everyone can really relate to an albatross, it's very difficult to relate to a tiny little storm petrel" (interview, 03.02.2021).

The charisma and public traction of albatrosses has a specific history (as discussed in the Introduction) but was also actively cultivated by involving elite and celebrity actors, like Prince Charles, in the cause of 'saving' the albatross. This, of course, has a broader precedent in elite, media-friendly initiatives to save charismatic marine megafauna. Anthropologist Jennifer Telesca (2020) argues these are characteristic of a mainstream environmentalism of the Global North which relies upon drama, celebrity, saviour plots, and blindness to its own complicity in ecological disaster. Awe is the crucial affective logic at work here. It foregrounds the 'spectacular', 'magnificent', and 'extraordinary' characteristics of the non-individuated

and non-speciated albatross. These characteristics, and their association with wildness and remoteness, align with what Dan Brockington (2008, 558–59) identifies as "a strong current of patronage of good environmental causes by the rich and famous…characterized by its support for remote, more exotic places, or its more general abstract causes, such as wilderness, biodiversity or charismatic species" (see also Igoe 2010; Spierenburg and Wels 2010). Campaigning efforts strove to amplify feelings of awe through partnerships with ocean-going adventurers as spokespeople who referenced their frequent encounters with albatrosses and evoked corporeal, experiential correspondences between the birds' lonesome, long-distance voyages in wild and remote places, and their own. At the abovementioned RSPB dinner, Prince Charles was joined by yachtswoman Dame Ellen MacArthur who was soon to spend a season in South Georgia, filming for the BBC documentary "Ellen MacArthur and the Albatross" (2007).

Corporate partners also joined campaigning efforts. Between 2000 and 2010, the Volvo Ocean Race, a round-the-world sailing event, lent financial support and publicity to the Save the Albatross campaign and the Albatross Task Force, foregrounding a close affinity between the intrepid heroism of competitive sailors and members of the Albatross Task Force in their communications.[34] Awe towards sailors, albatrosses, and those working to save them was encouraged simultaneously by evoking human and nonhuman bodies within similar frames. As with the Save the Albatross voyage, which followed the journeys of *wandering* albatrosses specifically whilst evoking albatrosses more generally, these practices have foregrounded the largest, most impressive, furthest travelling members of the species group, reinforcing existing cultural associations of 'the albatross' with the great albatrosses[35] specifically. Ornithologist Robert Cushman Murphy observed in the early 20th Century, "[t]o sailors, voyagers, and until recent times to ornithological recorders, any great albatross was merely *the* albatross" (1936, 541, in Barwell 2007). This has much to do with visual representations of Samuel Taylor Coleridge's poem 'The Rime of the Ancient Mariner,' discussed in the introduction as a powerful source Western cultural associations with

[34] See, for example, https://www.sailing.org/2007/04/11/volvo-ocean-race-supports-save-the-albatross-campaign/ (last accessed: 20.06.23)

[35] The great albatrosses are seabirds in the Diomedea genus of the albatross family, which includes wandering, northern and southern royal, Antipodean, and Amsterdam albatrosses.

albatrosses. Many of these representations depicted the albatross in the poem as white, emphasising its connections with Christianity and purity. Whilst none truly *are* white, Graham Barwell (2007, 39) notes how, therefore, over time, "Coleridge's bird and the notion of albatross in general become closely associated with the great albatrosses," the largest and whitest of the species group. Arthur, a seabird ecologist with the British Antarctic Survey, suggested that wandering albatrosses continue to disproportionately capture public interest because of their awe-inspiring characteristics:

> "they are a one-step-up, not like these more anonymous species. If you go around a trawler in the Falklands there's hundreds, thousands sometimes of black-browed albatrosses or white-chinned petrels but there's not that many wanderers and they are so big and impressive" (interview 26.03.2021).

However, whilst big, impressive bodies might appeal to elite, wealthy conservation patrons for whom wildness and otherness are key aspects of albatrosses' allure, they do not necessarily invite people into relations of concern and care. Trophy hunters, for instance, might be motivated to kill charismatic species because their aestheticised awe-some characteristics—nobility, fierceness, power, and so on—enable the performance of human (usually male) strength, chivalry, and social status (see Barua 2017; Beattie 2019). Indeed, if we look to historical encounters with albatrosses recorded in expedition diaries or photographic collections, awe co-exists, without apparent contradiction, alongside cruel, instrumental, and ambivalent treatment of the birds (see Figure 11). At the same time as sightings of albatrosses evoked strong emotive responses, they were also enthusiastically shot or snared on baited hooks for amusement, scientific study, food, or feather-collecting (Barwell 2007; Tickell 2000). These practices continued into the 20th Century even as those perpetuating them, sometimes in the name of science, made such claims as "I now belong to a higher cult of mortals, for I have seen the albatross!" (Murphy 1948).[36]

[36] In his natural history of albatrosses, 'Albatrosses' (2000), seabird ecologist W.L (Lance) Tickell details how Robert Cushman Murphy, with financial support from the American Museum of Natural History and the Brooklyn Museum, collected some 500 specimens of 55 seabird species and upwards of 100 sets of seabird eggs during his voyage to South Georgia on the whaling vessel 'Daisy' (1912-1913). This quote comes from his diary entry for 28 October, 1912, published in 1948 as 'Logbook for Grace, Whaling Brig Daisy, 1912-1913.'

Figure 11 - A dead wandering albatross is displayed next to the crew of the RRS Discovery on the 1901-04 British Antarctic Expedition. Reproduced with permission from the Scott Polar Research Institute, University of Cambridge.

The actors prominently involved in albatross conservation in the mid-2000s also indicate that awe was mobilised in ways that exceeded conservation logics. Scholars have noted how charismatic species become important to the construction and maintenance of nationalisms and in the performance of international relations (Barua 2017; Buckingham, David, and Jepson 2013). In materially tracing the circumnavigations of wandering albatrosses, the voyage of the 'English Rose VI' also charted and supported a kind of morally righteous British presence in, and identity linked to, these spaces. This was a tale of 'British fortitude' (see Kirby 2003), driven by a saviour narrative and aimed at British or anglophone audiences, mobilised also in Prince Charles' stated sentimentality towards the "poor old albatross" as stemming from encounters with "these extraordinary birds" during long voyages whilst serving in the Royal Navy (Cooper 2009). James Blair (2017, 580) observes how, in the Falkland Islands, a narrative of environmental stewardship "selectively reinforces Western norms and values" and allows settlers to "construct themselves as 'native' through environmental management." In UK Overseas Territories like the Falklands where around one third of the world's albatrosses breed, performances of concern for the birds, and practices of conservation generally (see De Santo 2020), are also performances of territorial

sovereignty, and reinforce narratives of human belonging through association with narratives of nonhuman belonging: "belonging (is) an interspecies dynamic", as Tom Fry writes (2023, 2; see also Lavau 2011). We saw this in Chapter Four as scientific research stations took over the infrastructure left by European colonial presences on sub-Antarctic islands. At issue here, then, are sentiments and stories whose functions, although they predominantly align with conservation logics, extend beyond them and the cause of 'saving the albatross.' In the next section I elaborate further on the relations between sentiments and conservation logics through an example where this alignment is less assured.

6.3.2. The awful albatross

In 2011, reflecting shifting winds of environmental sentiment, the Volvo Ocean Race that had supported the Save the Albatross campaign rallied behind a new cause – oceanic plastic pollution. In doing so, the event kept Wisdom, the Laysan albatross famous as the world's oldest known bird, as its official symbol and mascot, deploying volunteers dressed in plush, affably smiling 'Wisdom the albatross' costumes at events and as part of the Volvo Ocean Race Sustainability Education Programme for school children.[37]

Plastic pollution had recently come to widespread public attention as a significant threat to the continued survival of albatrosses and other forms of marine life through a much *less* endearing representation of Laysan albatrosses than the Wisdom mascot. American photographer Chris Jordan's photography series, 'Midway: Message from the Gyre' (2009) portrays dead Laysan albatross chicks decomposing to reveal stomach cavities filled with brightly coloured, recognisable plastic objects like bottle caps, lighters, packaging, and children's toys, which their parents had mistaken for food at sea.[38] The images circulated widely in news and social media and have become a touchstone of visual representations of oceanic plastic pollution. The location of these disturbing photographs, Midway Atoll, is a US National Wildlife Refuge in the central Pacific home to many different seabirds, including a large colony of Laysan albatrosses, and the site of the World War II Battle of Midway. Later

[37] See https://www.theoceanrace.com/en/rwp/news/12264_Kids-invited-aboard-The-Ocean-Race-Learning-Programme (last accessed: 20.06.23)
[38] See Chris Jordan's website for a selection of these images: https://www.chrisjordan.com/Midway/1/thumbs-caption (last accessed: 20.06.23)

coverage of Jordan's work intoned that there is a new battle underway at Midway - against plastic - and has presented albatrosses as "the casualties on the frontline" (Turns 2018, n.p.).

Captain Charles Moore is credited with the first description of high concentrations of suspended plastics in the currents of the North Pacific Gyre in 1997, which have been evocatively labelled 'garbage patches' after oceanographer Curtis Ebbesmeyer (see Gabrys 2016b; Gerhardt 2018). Jordan has described learning about these patches in a meeting of plastic pollution experts in 2008 and, in an extension of his existing photographic documentation of cultures of mass consumption, wanted to photograph the patches. He recalls being told, "you can't take a photograph of the Pacific Garbage Patch, it's spread out over a million miles, there's no place where it collects […] that actually doesn't exist," and relates how a colleague at the same meeting, aware of this intractability, turned to him and urged, "if you want to take a photograph of the Pacific Garbage Patch, go to Midway Island and look inside the stomachs of dead baby albatrosses."[39]

As Jennifer Gabrys (2016b, 138) observes, the "relative inaccessibility and invisibility of the [garbage] patches render them as looming imaginative figures of environmental decline and yet relatively amorphous and unlocatable and so seemingly resistant to environmental action." Jordan's images seek to address this by staging encounters with albatrosses' deaths, localising environmental decline in *these* bodies whilst evoking a sense of a contamination that is everywhere, shared across other less visible bodies. From the perspective of ecological scientists, these albatrosses function as bioindicators – the accumulation of pollutants in their bodies indicates their wider presence and damaging effects (see O'Brien, Kaneene, and Poppenga 1993). For Jordan, their role was akin to a messenger, and there was an important cultural currency to using albatross deaths for this purpose: "I thought it was strangely poetic that of all the possible birds that could be delivering this message to humanity, it's a legendary creature that already has a thousand-year history in poetry and literature as a warning and a carrier of messages: the albatross."[40]

[39] See Plastisphere Podcast, Episode 5, 'Visiting the Albatross': https://soundcloud.com/plastisphere-podcast/ep5-midway-message (last accessed: 21.07.23)

[40] See Plastisphere Podcast, Episode 5, 'Visiting the Albatross.' Here, Jordan is likely referring to (and misdating) Coleridge's poem, excerpts from which are also included in his later documentary film, 'Albatross', which also documents the effects of plastic pollution on the Laysan albatrosses of Midway Atoll.

As ‘sentinels of sentiment,’ albatrosses were made to deliver this message in the register of a warning intended to incite political action (see section 5.1 of Chapter Two).

The public awareness generated by Jordan’s photographs, and documentary series like *Blue Planet II* where albatross chicks are shown with items of regurgitated plastic, has been linked to progress towards addressing plastic pollution through resolutions such as the UN Environment Assembly’s ‘End Plastic Pollution: Towards an internationally legally binding instrument’ (2022; see Hogan 2019; Holden 2019; Mooney and Flood 2023). Sociologist Baptiste Monsaingeon (2013, n.p.), referencing Jordan’s images, argues that “these animals acted as early ‘sentinels’, exemplifying for large audiences an encroaching danger” from plastic pollution and catalysing action towards addressing it. Specifically, they exemplified this through appeals to sentiment: albatrosses’ bodies enable the ‘nonlocality’ of a ‘hyperobject’ (see Morton 2013) like global plastic pollution or it’s even larger choreographing force – a consumerist, single-use-oriented society – to become tractable and to register sentimentally, and it is specifically through an affective logic that seeks to shock, disgust, and horrify, that this is achieved.

This involves very different kinds of bodies to the previous section: these albatrosses are dead, decomposing, seemingly inanimate. Yet they are no less agentive, offering a striking example of how, as Mel Chen (2012, 2) observes, “matter that is considered insensate, immobile, deathly, or otherwise ‘wrong’ animates cultural life in important ways” (see also J. Bennett 2010 on “thing power”). Jordan’s images seek to amplify the affective force of these bodies by placing them into circulation online, creating new digital encounters which take place predominantly via the screen (see Turnbull et al. 2022). Media studies scholar Carolyn Pedwell (2017, 149) observes that, with this kind of imagery, “the wager is that a direct connection with sensation may engender what Brian Massumi (2002) refers to as a ‘shock to thought’: an affective jolt that works less to reveal truth as it does to ‘thrust us involuntarily into a mode of critical inquiry’ (Bennett 2005, 11).” Lorimer (2010, 249) observes that there is something “both voyeuristic and horrifically pornographic” about certain online animal representations that “target the gut instincts of repulsion and disgust.” Jordan’s images, too, present the viewer with a glut of death and decay viewed directly from above, filling the frame and devoid of context.

Described in media coverage as "beautiful, terrible photographs" (Fischetti 2009), and in Twitter responses as "stunning," "amazing and desperately sad," and "tragic and strangely beautiful," the images evoked widespread shock and revulsion, alongside trading in a kind of "toxic sublime" (Peeples 2011). The muted organic colours of feather and bone, alongside bright, recognisable inorganic plastics affords the images a disconcerting spectacular aesthetic appeal – there is an awe to this *eww*. This rendering awe-some of environmental pollution has, in other examples of photography of contaminated landscapes, been critiqued for its potentially depoliticising, sanitising, and paralysing effects (see Peeples 2011; Ray 2016).

The lack of context to these images – a characteristic feature of much spectacular nonhuman imagery encountered in digital spaces (Turnbull et al. 2022; Nelson, Hawkins, and Govia 2022) – has another significant effect. In portraying albatross death amongst the waste of consumer cultures, Jordan's work implicitly foregrounds a misleading causal relationship. At the level of seabird populations, major reviews of threats to seabird species globally conclude that plastic, although a growing threat (Wilcox, Van Sebille, and Hardesty 2015), "is not yet identified as a cause of seabird population declines" (Dias et al. 2019, 533) and "there is little evidence for serious problems" (R.A. Phillips et al. 2016, 176). Even for the individual birds shown in Jordan's photos, the conclusion we are visually guided towards - that they have been killed by plastics - is not necessarily correct. As Thom van Dooren (2014, 30) notes of Jordan's work, "it is hard to imagine that the cause of death of these birds could be at all uncertain. It seems, however, that very few of them die as a direct result of consuming plastic." Sandra, an RSPB programme manager, explained of her own time on Midway:

> "it's horrible, that island is just covered in plastic, but even there the researchers are quite frustrated [by the idea] that the plastic is killing all the birds. Actually, a lot of the birds would have died anyway because if you look at general fledging success it's not 100%, 60% would be great. On that island when the chicks die, yeah, they have plastic in them, but they have no idea if that's actually killed them or if it's just normal mortality" (interview, 24.02.2021).

Whilst this is a vital insight, these images were not put into circulation specifically to highlight the threat of plastic pollution *to* albatrosses, neither were they taken *by* albatross

conservationists or intended *for* an albatross conservation campaign. Their intention, as articulated by Chris Jordan, was to highlight the problem of oceanic plastic pollution, with albatrosses as a culturally appropriate sentinel or messenger, and to evoke sentiments amongst a more general audience that might build towards a political response to this problem. Albatrosses themselves are de-centred, as they become an apt metaphorical device for centring plastic pollution as a crucial contemporary environmental concern, captured in observations that oceanic plastic pollution has become "our modern albatross," evoking the bird hung around the mariner's neck in Coleridge's poem (Hogan 2019), and in illustrator Nick Hayes' (2011) 'The Rime of the Modern Mariner,' which portrays an albatross dead from entanglement in plastic and a ship stranded in the North Pacific Garbage Patch.

The issue, from the perspective of albatross conservation, is that these mediations and the sentiments they appeal to do not necessarily align well with conservation projects, even as they shape the worlds in which these projects operate. A tension emerges between a politics grounded in sentiment and one grounded in scientific rationale, with the effect that plastic pollution – to the frustration of some ecologists and conservationists – has become disproportionately significant in public narratives of threats to the birds. This is viewed with some concern as diverting public interest from, and perhaps constraining action on, the threats which most concern conservationists. Sandra, for instance, suggested that "with bycatch, it's harder to relate your actions to causing that, it's just some far away thing that happens at sea that most people won't have heard of. I think a lot of conservation issues are like that, even climate change, it's hard for people to relate whereas with plastic its clearer. It's a bit of a source of frustration sometimes that the plastic side of things gets such a lot of attention compared to the other major threats, because really invasive species[41] and bycatch are the big things" (interview, 24.02.2021). What new sentimental strategies, then, have conservationists deployed to keep their agendas circulating and capable of making a difference in online worlds replete with multiple affective albatrosses that pull people towards different sentiments and forms of engagement?

[41] This refers primarily to invasive mammals, such as mice and rats, which have been introduced often accidentally to the islands where seabirds breed and prey on their eggs and chicks (see Dias et al. 2019)

6.3.3. The endearing albatross

Taiaroa Head, a peninsula in the Southeast of Aotearoa New Zealand's South Island, is renowned as the only mainland breeding colony of albatrosses in the Southern Hemisphere and one of the few places globally where publics can readily encounter these birds on-shore. Some 100,000 visitors journey to the site each year to see its Northern Royal albatrosses. An even greater number of interested visitors, however, now tune in to view Taiaroa Head's albatrosses online.

The Royal Albatross Cam was set up by the New Zealand Department of Conservation in 2016 to observe, and offer online audiences a continuous livestream of, the albatrosses breeding at Taiaroa Head.[42] In 2019, The Cornell Lab of Ornithology's Bird Cams, an initiative which aims to encourage "awareness and inspiration that can lead to conservation, education, and engagement with birds" through globally distributed camera livestreams joined as a partner in the delivery of the livestream (see The Cornell Lab 2023). Each breeding season, the livestream follows a different 'Royal family' from egg-laying and incubating in November/December through to the fledging of the single chick in September the following year. There is an annual thematic 'name the chick' competition, while the chick's parents are assigned more anonymous monikers according to the colours on their leg bands (like GLY - Green/Lime/Yellow). The Cornell and NZ Department of Conservation webpages for the camera provide background to each family, information about albatross behaviour, the Taiaroa Head colony, and conservation activities, whilst video 'highlights' and news delivered via the @RoyAlbatrossCam Twitter account focus particularly on the 'cute' everyday antics of the chick and chick-parent relations. The webcam has been described as "an unexpected global hit, with 2.3 million people from 190 countries tuning in to watch the endangered birds rear their chicks" (Roy 2019, n.p.).

One moment captured by the webcam circulated especially widely when an albatross arriving to feed its chick had an unexpected 'crash landing,' ending up upside down wiggling its feet in the air to right itself. This clip on the @RoyAlbatrossCam Twitter has been viewed

[42] See https://www.doc.govt.nz/nature/native-animals/birds/birds-a-z/albatrosses/royal-albatross-toroa/royal-cam/ (last accessed: 21.07.23)

over 1.5 million times,[43] with YouTube spin-offs like 'Albatross Attempts Landing, Fails Spectacularly!', and the event was covered by various news organisations worldwide. Part of the moment's appeal was the way it seemed to make the bird more sympathetic and relatable by subverting associations of the albatross with aerial grace – what conservationist Carl Safina (2002, 2, original emphasis) calls the "almost overwhelming *musicality* of an albatross in air." A CNN journalist mused, "one clumsy albatross might have just ruined this illusion" (McSweeney 2021).

The Royal Albatross Cam illustrates a growing practice of leveraging the 'cuddly charisma' (J. Lorimer 2007) of albatrosses as vectors for conservation concern. Made possible by social media and the liveness of continuously accessible online webcams, this seeks to locate care and concern in the intimacies of albatrosses' terrestrial, (inter-)individual lives, localised around the bounded spatiality and homely domesticity of the nest, rather than the awe-some vastness and otherness of their oceanic lives. Whilst conservationists are not notorious for their concern for individual animals, favouring an ethics premised on populations or species or "care for the collective" (Srinivasan 2014; see Biermann and Mansfield 2014; Braverman 2017), some important concessions are made to individuation here. Audiences are encouraged to care about albatrosses generally through attachments formed with individual birds, in contrast to the more generic evocations of 'the albatross' encountered previously. Emphasis is placed on particular kinds of albatross body: above all individual, often named, chicks, presented as cute, fluffy, vulnerable, and endearing, and those bodily features or behavioural characteristics amenable to anthropomorphism. These are not innocent representations: they invite a sympathetic, but also patronising and unequal, mode of relation and tend towards a fetishised depiction of albatrosses' pair bonds and heteronormative nuclear family units (see Perret 2023). This contrasts with a growing body of work documenting relational dynamics amongst albatrosses which diverge from this narrow norm, like high 'divorce' rates (e.g. Sun et al. 2022), and the prevalence of same-sex partnerships (Young and VanderWerf 2014); dynamics which are rendered invisible here.

[43] See https://twitter.com/RoyAlbatrossCam/status/1368153295634636804 (last accessed: 25.07.23)

Organisations encountered in earlier sections enthusiastically mobilising awe-some albatrosses have turned to *aww* – the cute, cuddly, and endearing - as an important new affective logic shaping their communications. The RSPB and BirdLife International's 'Albatross Stories' campaign, for instance, follows a chosen set of 'albatross stars' breeding at Bird Island, South Georgia and invites social media audiences to tune into regular curated updates about their lives, participate in naming chicks, and learn about the work of the Albatross Task Force. Text accompanying the images posted to social media often has an explicitly conservationist focus, highlighting threats facing these birds, particularly fisheries bycatch. The reasons for the growing prominence of this affective logic are at least twofold.[44] First, as Maddox (2022, 16) observes, the internet is awash with *aww,* part of a "cute economy (which) posits not only that digital cute content is in high supply but that it is also in high demand." The kind of imagery used in the Royal Albatross Cam Twitter and the Albatross Stories campaign, in this context, be viewed as an effort by conservationists to adapt their visual messaging to the logics and demands of digital cultures, adopting framings and aesthetic formats that are seen to circulate more effectively and lead to more 'meaningful encounters' that "enact a shift in sensory perception" (H. F. Wilson 2017, 458) in online worlds.

Secondly, *aww* is not just a distinct affective logic to those encountered earlier but is also positioned deliberately in opposition to them. The specific audiences targeted by this messaging shape this approach. The RSPB and partner organisation BirdLife International, for instance, are wary of using the kind of shocking imagery discussed in the previous section, and have come to favour positive, hopeful messaging and images and text which attempt to build rapport with and affection towards (sometimes individuated) albatrosses amongst particular audiences.[45] In a public presentation to the South Georgia Association, Yasuko Suzuki, a BirdLife International Marine Programme Officer, explained how the Albatross Stories campaign is significantly targeted towards Japanese audiences, with Japanese

[44] See https://www.instagram.com/albatross_stories/ (last accessed: 23.07.23)
[45] This was brought up by RSPB and BirdLife International staff in a session I attended on 'Seabird Bycatch in Commercial Fisheries' at the World Seabird Conference 2021. It is also evidenced through analyses of these organisations webpages and social media accounts.

language social media accounts alongside English language accounts.[46] Japanese and other East Asian nations' fisheries cause significant seabird bycatch, but as Euan Dunn, marine advisor at the RSPB, and colleagues (2007, 168) observe, conservationists seeking to influence decision-making in these nations have sought to work sensitively "against the anti-whaling legacy which has fomented a general suspicion of environmental NGOs." The Albatross Stories campaign forms a recent part of this work, oriented towards increasing Japanese public awareness of albatross bycatch. As Suzuki explained, "cute albatrosses are really important for the audience to feel connected and feel affectionate about those albatrosses because that's the first step they start caring and developing a desire to protect albatrosses from threats like fisheries bycatch."[47]

Cute albatrosses, then, are seen to avoid inflammatory or confrontational sentiments, and facilitate the communication of complex, thorny issues in positive registers in a sensitive cultural and political context. This approach recalls concerns described in Chapter Five that Ocean Sentinel's model of surveillance would create antagonism between conservation and fisheries interests. Here too similar dynamics motivate decisions to use or avoid certain kinds of imagery and narratives. By way of a logic that "cute things evoke in us a desire to protect them" (Ngai 2010, 950), the hope is that this encourages people into relations of care in ways that are more difficult to achieve with other kinds of mediated albatross body. For Sianne Ngai (2010), cute aesthetics appear as politically ambivalent or inconsequential and, indeed, several scholars have questioned their political potency (e.g. Maddox 2023; Page 2016). Thom van Dooren (2011, 294) has highlighted how aesthetic motivations in conservation and peoples' preferences towards the flourishing of some species over others based on their aesthetic appeal can lead to questionable biopolitical interventions carried out in the name of conservation but for which, in reality, "there are no real conservation objectives" (see also Marris 2021). Indeed, conservationists working to conserve less endearing and charismatic seabirds also affected by fisheries bycatch express regret about the lack of attention these

[46] See South Georgia Association Talk 'Saving Ocean Wanderers: Why Japan is important in the fight to save South Georgia albatross" https://www.youtube.com/watch?v=b-zsG9YpVx0&t=3313s (last accessed: 23.07.23)
[47] Ibid (53:30)

birds receive in comparison with albatrosses.[48] Whilst cute albatrosses might, then, invite people into relations of care, as George Cusworth (2023, 1) observes, "there is often a violence committed in care's name." Here, particular kinds of bodies are elevated as worthy of care based on their cute aesthetic appeal, simultaneously creating a set of other bodies that become less visible or liable to benefit from conservation interventions configured by these aesthetics.

6.4. Conclusion

This chapter has so far detailed three cases through which to understand albatrosses as 'sentinels of sentiment;' as beings that convey, through various mediations, environmentalist and conservationist messages through their appeals to sentiment (see Table 4).

[48] One participant in the abovementioned World Seabird Conference 2021 session commented "there's not much conservation attention to the problem of seabird bycatch in gillnet fisheries, and one of the issues is the species involved, usually bycaught seabirds in gillnets are less charismatic than the ones caught in longline fisheries. Not many people care about the velvet scoter compared to a wandering albatross so I think we just need to raise the profile of other species, but I think it comes down to the charisma of species."

Table 4 - Summarising sentiments

Logic	Focus	Affordances	Mobilised via	
Awe	- Wildness - Otherness - Spectacle - Symbolism (ecological health; positive human-nature relations; vastness of the oceans)	- Large/adult animals - Life-histories - Mobilities - Remote geographies - Generic (non-speciated/individuated)	- Photography - Documentary - Literature - News media - Campaign/ fundraising events (celebrity)	
Eww	- Shock - Disconcertion/ disturbance - Spectacle - Symbolism (degradation; contamination; negative human-nature relations)	- Dead/ suffering animals - Parent-chick relations (toxic transfers) - Generic (non-speciated/individuated)	- News media - Social media - Photography - Documentary	
Aww	- Cuteness - Sympathy - Relatability - Endearment - Storying individuals	- Chicks - Pair bonds - Parent-chick relations - Terrestrial lives - Individuated	- Photography - Social media	

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The ways in which albatrosses are mobilised as sentinels here are distinct from their roles as sentinels outlined in previous chapters. Breeding success rates, population statistics, and other forms of biological and environmental data are not the primary vectors through which calls to action are formulated and conveyed here. Instead, scientific, reason-based

logics are secondary to, although not necessarily replaced by, those which operate more affectively. Cross-pollination between reason- and sentiment-based logics in conservation science and practice is increasingly commonplace. As I discussed in section 5.1 of Chapter Two, some scientists have critiqued the ways in which non-scientific rationales are involved in the mobilisation of sentinel animals and have come to configure scientific and conservation practice.[49] However, while the mobilisation of sentinels discussed in previous chapters is explicitly tied to the practices of scientists and conservationists, this chapter has illuminated sentinels (also referred to as spirits, symbols, and messengers) as more promiscuous. They are liable to mobilisation by more varied actors (photographers, documentarians, journalists, philanthropists, etc.), for different purposes.

This entails a subtle but important shift for understandings of what sentinels are and how and to what ends they act, with implications for developing sentinel geographies as a field of geographical inquiry. At issue here is a tension between a notion of the sentinel as a *proxy* and as something that is valuable in itself; in essence, a tension relating to what is being signalled and what kind of a response is called for. Andrew Lakoff (2016, 240) writes that a sentinel animal is not necessarily "valued for its own sake but rather serves as a proxy in a struggle against a broader catastrophe." Seabird conservationists mobilise albatrosses as a proxy for the state of their wider marine ecosystems and other seabirds, but they do so primarily in order to attract attention, funding, and political goodwill to the causes of seabird conservation. As I have shown, they do so in different ways to speak to different audiences and in doing so focus on different affordances of the birds. The implication is that the sentiments that are cultivated as a result will have a direct and positive impact on the conservation status of the birds. Other actors, as I illustrated through the example of Chris Jordan's Midway photography series, figure the locus of action slightly differently. The birds are still used as sentinels of sentiment, but these sentiments are only partly directed towards the birds themselves. Here, it is *because* people care (or might be made to care) about albatrosses, that they assist in encouraging them to care about something else.

[49] Even as several of these scientists described to me in interviews how, whilst there has been a proliferation of scientific data about sentinel animals and their ecologies, this has not translated well into environmental policy or practice.

This unsettles three relationships, two of which have been central in the uses of sentinels encountered so far in this thesis: first, between sentinel animals and conservation practices. Animals can be effective sentinels while the benefits of this accrue to something which, while not entirely separate from conservation activities, is still different – like international action to address plastic pollution. This differentiates sentinels of sentiment from the related 'flagship species,' which is a strategic figure deployed to benefit conservation. As in the previous chapter, where I questioned a narrative that albatrosses stand to gain from their enrolment in conservation surveillance, here too the relationship between an animal being a sentinel and its wellbeing – individually and collectively – is uncertain.

The second unsettled relationship is between sentinel animals and scientific evidence: through appealing to sentiment, animals can be effective sentinels of something against the grain of a reason-based model of action. We saw this manifest in the frustrations of conservationists towards the growing prominence of plastic pollution in public understandings of threats to albatrosses at the expense of attention towards threats seen as more significant. This has also been illustrated with other animals, like polar bears, which have been mobilised as sentinels of climate change, but are then also used by other actors to support narratives and policy choices in ways that appeal effectively to sentiment but are fundamentally in tension with scientific evidence (Tyrrell and Clark 2014; see also Harvey et al. 2018). This is not to draw a firm line between reason and sentiment, clearly these are closely interrelated and we also saw how, when sentiments lead in directions and towards outcomes that are aligned with conservation prioritisation (such as in the first section where elite figures mobilised albatrosses to support their own nationalist or philanthropic narratives, which conservationists even encouraged through the alliances they forged with these figures) this is not resisted.

The third relationship is between bodies and sentiments. As I suggested in section 2, sentiments flow from (mediated) encounters between bodies, and these encounters have transformative potential. Various strategies have been developed by conservation practitioners to anticipate this potential. Sophisticated marketing research techniques, for instance, are used to quantitatively model nonhuman charisma and human preferences

towards particular species, to effectively target conservation campaigns towards local or international audiences (e.g. E. A. Macdonald et al. 2015; Verissimo, MacMillan, and Smith 2011). Yet although certain bodily affordances might prime animals for certain kinds of sentiment, and these can be tapped into and perhaps even cultivated into being towards conservation actions, sentiments cannot be wielded in the same way that scientists and practitioners might seek to wield data about ecologies or animal populations. They are not liable to capture by scientific models and are more unruly in the transformations they portend.

Indeed, an apparent risk to both researchers and conservation practitioners in setting a particular animal in motion as a sentinel based on its appeal to sentiment is a loss of control over narratives and desired outcomes; the animal in question becomes part of larger, more complex collectives and is enacted as a sentinel through different practices which they cannot directly influence. For instance, the logics of *awe, eww*, and *aww* I have described, whilst mobilised separately, are clearly reliant upon and build on each other in sometimes predictable, sometimes surprising ways. The dead albatross is shocking and horrifying because of these birds' usual association with liveliness and distance from human worlds; and the clumsy albatross becomes an unexpected international sensation because it subverts associations of the birds with unrelatable aerial grace and majesty. The affective force of these mediations also takes shape in relation to existing cultural associations, the logics of online cultures, emerging environmental awarenesses amongst different publics, and so on. The point here is that the relationship between bodies and sentiments is uncertain, emerges processually, and is liable to multiple configurations: bodies, human and nonhuman, always incubate the potentials to do and become differently (see J. Lorimer 2010; McCormack 2013; Thrift 2004).

How then, might researchers proceed from such an indeterminate observation? I make three suggestions. First, there are clearly still *some* consistencies in which animals are mobilised as sentinels of sentiment and how and my focus in this chapter has intentionally been on a group of animals that occupy a privileged place in an "affective taxonomy of the nonhuman realm" (J. Lorimer 2007, 914) in order to draw this out. This will be a helpful intervention for future sentinel geographies focused on some sentinels, and less for others.

Mussels, lichens, and small estuarine fish, for example, are all sentinel species even while their affective allure and the public interest they engender may be limited (Gabrys 2018; Gramaglia and Sampaio da Silva 2012; Lakoff 2016). Future work might investigate specifically how the agencies of such sentinel beings contrast with those that more strongly evoke sentiments, as it might also explore the effects that sentinels of sentiment have on the beings they co-habit with. The deliberate naming of BirdLife International's seabird bycatch initiative as the Albatross Task Force and Chris Jordan's focus on albatrosses over other seabirds living on Midway Atoll both illustrate that other animals share the fates of albatrosses even as their public profiles are more marginal, and the way sentiments are channelled can (unintentionally) further this marginality. The governance implications of such uneven sentimental geographies merit further exploration. Secondly, in line with recent work that has attended to the materialities of digitised worlds and attended ethnographically to how environmental politics is configured by online spaces (e.g. Hawkins and Silver 2017; Turnbull et al. 2022), there is further scope here to consider through digital ethnographic research how sentinels of sentiment circulate online and affect the participation of publics in environmental politics.

Lastly, if there is no monopoly over defining how people respond sentimentally to environmental change via sentinels, this opens up possibilities for creative practical engagements with sentinels' transformative potentials. My decision to frame the examples in this chapter as 'albatross stories' derives from Thom van Dooren's suggestion that scholars in the environmental humanities and social sciences might themselves develop modes of storying the more-than-human ethical stakes of biodiversity loss and environmental change in ways that travel "far and fast – like an albatross riding the wind in search of food" (Van Dooren 2014, 21). By identifying the geographical and temporal limits to the circulation of the kinds of stories I have detailed here (for instance, recognising that awe-some albatrosses appeal to a very specific predominantly Western audience), might it be possible to develop new kinds of stories which evoke and engage with sentiments differently? Sentinel geographies might in this way develop recent geographical scholarship concerning new forms of storytelling and experimental practices for engaging animals' worlds (e.g. Cameron 2012; Gandy 2021; Hodgetts and Lorimer 2015), extending beyond a project of critically interrogating environmental sentinels in use towards itself storying sentinels in new ways.

Chapter Seven

“Eyes on the seas”

Glitches in smart ocean transformations

7.1. Introduction

This chapter shifts empirical attention from the 'on-bird surveillance' discussed in Chapter Five to the 'on-board': technologies and approaches by which data are generated about and aboard fishing vessels. This data, produced through an expanding but geographically uneven array of monitoring activities forms a key part of efforts to increase oversight over the global fishing industry and develop more effective fisheries governance regimes. The chapter focuses on electronic monitoring (EM), a digital solution to on-board fisheries data collection. Where the Ocean Sentinel albatrosses in Chapter Five were described as 'spies in the sky,' EM systems have been described as 'eyes on the seas' (Drakopulos 2019). They produce video, location, and sensor data which allow fisheries managers to remotely track the activities and catches of individual fishing vessels and entire fleets, and are held to deliver a range of benefits over existing approaches to monitoring fisheries (see Gilman et al. 2019; Helmond et al. 2020). A range of governmental, non-governmental and corporate actors are promoting EM as a key tool for achieving sustainable fisheries (e.g. Fujita et al. 2018; Michelin and Zimring 2020; NOAA Fisheries 2022). Seabird conservationists are seeking to influence how EM programmes are configured so that the data they produce informs more seabird-friendly fisheries where bycatch of birds is significantly reduced, building upon their efforts discussed in Chapter Five to map where fishing vessels and species like albatrosses co-occur in marine space (Gilman et al. 2021; see also McElderry et al. 2004).

EM occupies an ontological status somewhere between a promissory and an already existing solution to fisheries monitoring. Despite existing since the 1990s, a sizeable gap exists between the discursive prominence of EM systems in debates about fisheries transparency and sustainability and operational realities. In terms of the global fishing fleet, coverage by fully operational (i.e. non-trial) EM programmes is a drop in the ocean – some 770 fishing vessels out of an estimated global total of 4.1 million (Helmond et al. 2020; FAO 2022). The challenges faced in transitioning towards this digital, data-driven approach to fisheries monitoring, and in realising its promise of greater transparency, are a key focus of this chapter. This focus derives from a desire which I began to articulate in Chapter Five to move beyond analyses which take enhanced surveillance and control as the rationales for and – crucially for this chapter – (almost inevitable) outcomes of the deployment of digital

technologies for environmental purposes. Aligning with research (discussed in section 3.3 of Chapter Two) in digital geographies, media studies, and STS interested in the frictions, glitches, and tensions that shape digital and data-driven transformations in ways of knowing and governing (e.g. Bates 2018; Bowker 2000; Edwards 2010; Leszczynski 2019), I foreground the glitchy[50], tension- and friction-filled dynamics involved in the operation of EM systems as important entry points for empirical analysis of these systems and their effects in the world. Adam Searle and colleagues (Searle et al. 2023, 3, original emphasis) observe that "*glitches* in the deployment of digital technologies […open] varied avenues for geographers to rethink majoritarian narratives of the technonatural present." This chapter is offered as a modest contribution towards this rethinking and addresses the research question: "*How are the promises of digital ocean governance complicated in practice and with what consequences for seabirds and marine ecologies?*"

My approach and focus intentionally contrast with accounts of digital surveillance as a technique of government deployable "potentially everywhere and against everyone" (Petit 2020, 30; see also Gregory 2011), and I offer an alternative register of analysis to geographical and political ecology literatures which foreground the capacities for digital technologies in environmental governance to further concentrate decision-making authority amongst experts and elites (Adams 2018), produce "hegemonizing knowledge regimes" (Machen and Nost 2021, 555), and cement "neocolonial and racialized power structures" which reproduce injustices (Nost and Colven 2022, 23). My intention is not to suggest that EM technologies could or do not have such effects. Rather, it is to show how foregrounding these may obscure the specific relational dynamics of particular surveillance regimes and the agencies of humans and non-humans under the 'surveillant gaze' to shape the scope of these regimes. This is an intention shared in part with literatures in geography and adjacent fields that outline the challenges that oceanic spaces and lifeforms present to terrestrially-grounded ways of knowing and governing (see Bear 2013; Lehman, Steinberg, and Johnson

[50] There is, as I discussed in Chapter Two, a specific conceptual legacy to the use of the term 'glitch', tied to feminist science and media studies (see Leszczynski 2019; Nunes 2012; Russell 2020b). This concerns, particularly, the glitch as both error (a malfunction or digression from intended operation) and erratum (as an opening for doing things differently and correcting for better, more just or equitable outcomes). Here, I use glitch more broadly and simply to describe instances where digital technologies fail to function in intended ways and where discourses which promote digital solutions are undermined or interrupted by these failures.

2021; Steinberg and Peters 2015), and which try to develop 'milieu-specific analyses' appropriate to the ocean as a space for/of social thought (Jue 2020; see also Helmreich 2015). The chapter demonstrates that the specific milieu in which digital fisheries monitoring unfolds challenges the scope of its ambitions and, in so doing, it moves beyond 'celebration or critique' of 'smart ocean' transformations to attend empirically to what these transformations are, how they (sometimes don't quite) work, and how they might affect the dynamics of ocean governance (see Drakopulos et al. 2022).

I begin by describing how EM systems function and their promise for fisheries governance. In the sections that follow, I parse the milieu-specific challenges this mode of surveillance faces into upstream (resistance by fishers to the deployment of EM on their vessels), on-board (the materialities of vessels and the marine environment, the glitchiness of EM hardware, and deliberate acts of sabotage), and downstream (human and automated modes of reviewing the data EM systems generate) elements. Each demonstrates how the normative ambitions invested in EM systems are shaped by the specific characteristics and qualities of their operating environment and the humans and nonhumans they seek to survey, which complicate their smooth subsumption by computational logics. In the context of the thesis' overarching aims, this chapter is not *directly* an account of seabirds as sentinels. However, it extends my argument by showing how the dead seabirds encountered by EM technologies on-board vessels do not necessarily function well as sentinels, and relatedly that seabirds can fail to materialise as sentinels in the absence of the collectives and practices required for them to do so (as discussed in Chapter Two). In contrast to the lively qualities described in Chapters Four and Five, such as seabirds' visibility and amenability to study, dead seabirds' bodies are difficult and costly to find in EM data, often are not explicitly looked for, and in some instances are deliberately obscured from view. If, as Gramaglia and Sampaio da Silva (2012, 190) observe, sentinels are effective at 'speaking' for their environments and making the problems affecting them known, I illustrate in the latter half of this chapter that it is hard to make dead seabirds do so in this context.

7.2. Fishing for data

In a promotional video for the Environmental Defence Fund (EDF) titled 'Fishing Smarter: how new technology can help our oceans thrive', EDF programme manager Chris Cusack describes the fishing industry as "stuck in the dark ages in terms of [monitoring] technologies."[51] The 'dark ages' has a dual meaning here. Firstly, the fishing industry worldwide has been slow to adopt digital monitoring technologies for the surveillance of workplace practices compared with other industries. Secondly, as we saw in the Chapter Five, some see this as abetting a widespread "culture of secrecy" (Nimmich and Goward 2007, 58) which keeps fisheries managers 'in the dark' and maintains the viability of regulatory noncompliance and 'dark' or IUU[52] fishing activities. As I outlined in the introduction to this thesis, an array of 'smart ocean governance' initiatives, increasingly co-ordinated by non-state actors, attempt to address this lack of oversight through enhanced surveillance of marine space using digital technologies, guided by a principle that "data renders the oceans, and the activity therein, visible to policy…[and] that data creates, and is essential for, transparency" (Drakopulos et al. 2022, 2; see also Bakker 2022; Gray 2018; Ritts and Simpson 2022).

Captured by such tropes as "you can't manage what you can't measure,"[53] these 'smart ocean governance' approaches cohere around a logic of "measurementality." As discussed in section 3.3 of Chapter Two, STS scholars Esther Turnhout and colleagues (2014) use measurementality to describe and critique the crucial role of transparency – achieved through techniques of measurement, quantification, and standardisation – in contemporary neoliberal environmental governance. Transparency is held to contribute to the effectiveness and efficiency of governance; to democratisation in the sense that claims regarding the achievement of environmental targets can be validated by civil society; and to the improvement of performance on the basis that actors become subject to and respond to greater external scrutiny (a form of neoliberal governmentality). Measurementality informs

[51] Fishing Smarter: How new technology can help our ocean thrive https://www.youtube.com/watch?v=xjlvPIqAuis (2:55) (last accessed: 23.07.23)
[52] As a reminder from Chapter Five, this acronym refers to illegal, unreported, and unregulated fishing
[53] As offered by The Nature Conservancy's Marine and Fisheries Research programme manager Kydd Pollock in a session of the Seafood and Emerging Technologies conference (24.09.20); and Robert, Interview, 16.04.2023

the view that the 'dark ages' of the fishing industry are prime for reform via technology- and data-driven solutions. A key component of this concerns data collected on-board fishing vessels, where existing approaches are perceived as particularly deficient.

Currently this data, where it is generated at all, flows primarily from logbooks, where vessel captains self-report on their activities and catch, and independent fisheries observers who collect data and samples during fishing trips. In many fisheries, independent observer coverage is low, often less than 1 percent of vessels, such that logbook records are often the main source of data (Brown et al. 2021; Helmond et al. 2020). Studies demonstrate underreporting of catch and bycatch in logbooks and discrepancies between self-reported and independently collected data and note that fishers often change their practices in the presence of observers or even intimidate or bribe observers into misreporting (Brown et al. 2021; Gilman and Zimring 2018; Emery et al. 2019; Gilman et al. 2019).

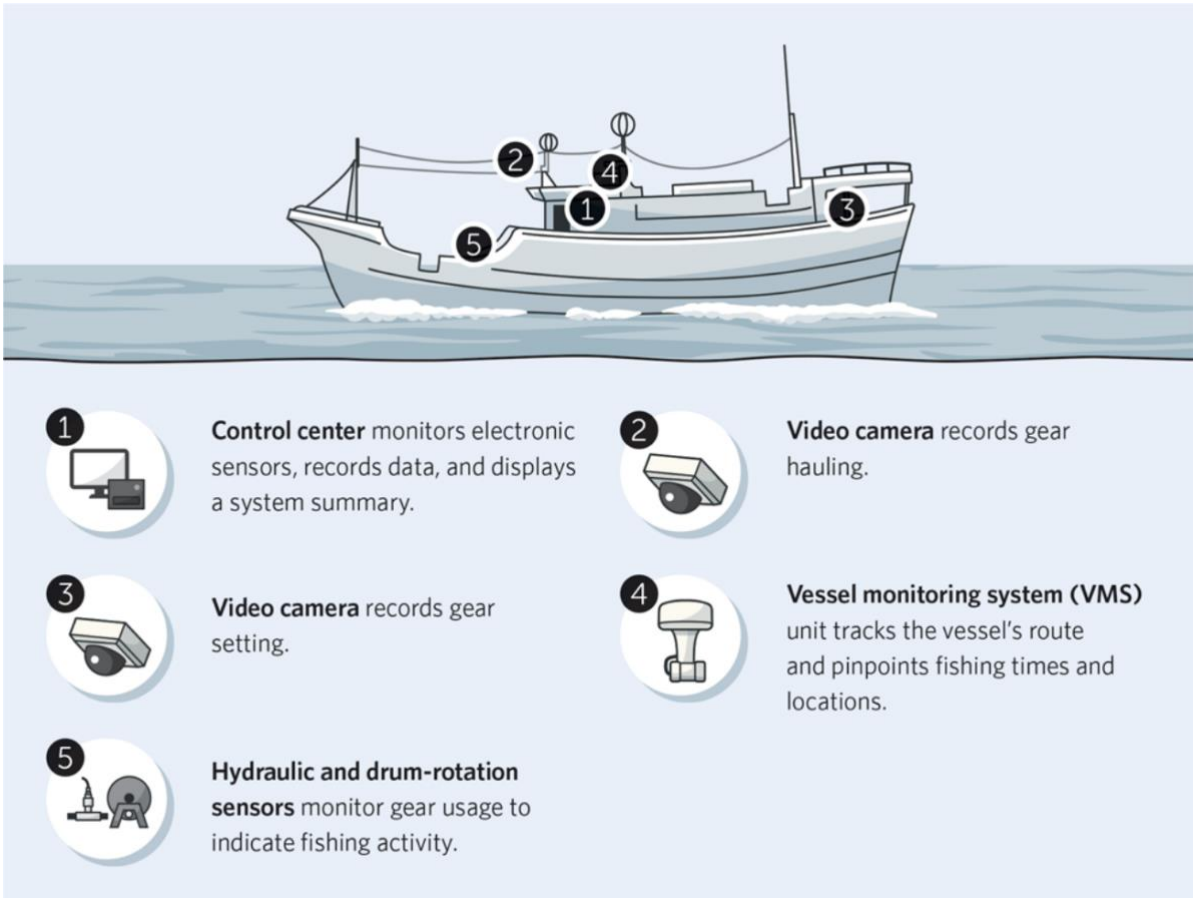

Figure 12 - A diagram of electronic monitoring system components. Copyright © 2019 The Pew Charitable Trusts. All Rights Reserved. Reproduced with permission. Any use without the express written consent of The Pew Charitable Trusts is prohibited.

Electronic monitoring (EM) systems are a solution that environmental NGOs, researchers, national governments, some fishing industry actors, and of course the private companies which develop these technologies, are widely promoting to address these issues.[54] These systems generally comprise video cameras mounted to different points on a fishing vessel recording footage of fishing activities, a GPS unit which records location data and provides a measure of vessel speed, and, in some systems, sensors which indicate when fishing gear is being set and hauled. Cameras, GPS, and gear sensors are wired into the boat wheelhouse, where a display shows camera views and other information, and a computer unit monitors the system and records data onto a hard drive (see Figure 12). Hard drives are typically physically collected from the vessel, and the data are reviewed by data analysts from government agencies or private contractors using EM review software (discussed in section 5) and reported to fisheries management bodies (see Gilman et al. 2019). In systems designed for smaller vessels, these different components are sometimes integrated into a single tablet.

For now, EM largely supports the existing monitoring requirements of fisheries management, fulfilling a combination of scientific and compliance monitoring purposes, but visions for what EM might enable include the ability to assess fish stocks based on actual catch data from entire fleets, enabling adjustment and allocation of catch quotas in near-real-time; the large-scale visual assessment of compliance with conservation measures like using seabird bycatch mitigation techniques; and capacities to know bycatch more comprehensively by visually identifying and quantifying the number of individual animals caught (Michelin, Sarto, and Gillett 2020; Qiao et al. 2021). Per Michel Foucault's (1975) conceptualisation of surveillance as enabling both observation and management, EM is also imagined, and demonstrated, to directly govern the conduct of fishers according to the expectations of fisheries managers; for example, by incentivising accurate logbook reporting

[54] Prominent environmental NGOs supporting EM include the Pew Charitable Trusts, The Nature Conservancy, WWF, and the Environmental Defence Fund; the US and Canadian governments have been early adopters and funders of these systems through agencies like NOAA and the National Marine Fisheries Service (US) and the Department of Fisheries and Oceans (Canada); and technology providers include Archipelago Marine Research, Saltwater Inc., Marine Instruments, Teem Fish, and many others.

or use of bycatch mitigation measures (Emery et al. 2019). These proposed benefits are summarised in Table 5.[55]

Table 5 - The proposed benefits of EM as a fisheries monitoring tool

Proposed benefit	Explanation
Accuracy	Accurate location and time data. Accurate assessment of gear type, total catch for certain gear types, and use of bycatch mitigation measures. Incentivises accurate logbook reporting, when logbook data can be compared with EM data.
Collection of multiple types of data	Multiple cameras offer multiple simultaneous views. Video, location, timing, and fishing activity data can be collected simultaneously. Video can be rewatched multiple times to meet several monitoring objectives.
Continuous data collection	In contrast with human observers, EM systems don't need to sleep or take breaks and can record data irrespective of weather conditions.
Data integrity	In contrast with human observers, EM systems are not subject to coercion, intimidation, or bribery. Data can be independently verified.
Safety and simplicity	Eliminates concerns over workplace safety for human observers and overcomes logistical difficulties of getting human observers to and from vessels.
Compliance	Because of the above, compliance with catch quotas, logbook reporting requirements, use of bycatch mitigation measures, etc., can be more effectively monitored and fishers may become more compliant if monitored and penalised for non-compliance.
Cost-effectiveness	Whilst up-front costs of system purchase are high, in the long-term EM systems are held to be less costly than human observer programmes.
Space-efficiency	EM systems take up a fraction of the space on vessels that human observers do.
Scalability	As EM is generally more cost-effective and space-efficient than human observers, these systems can be deployed on a greater number and range of vessels, with a normative goal of 100% of vessels and fishing effort monitored.

[55] Summarised from review papers by Emery et al. 2019; Gilman et al. 2019; Michelin, Sarto and Gillett 2020; Michelin and Zimring 2020; Pierre et al. 2022; van Helmond et al. 2019

7.2.1. Troubled waters

Enthusiasms for EM and fisheries reform through more and better data are not entirely new, despite their present prominence. As Drakopulos (2019, 5) notes, fisheries science in the late 1980s took a "distinctly neoliberal turn as at-sea data collection…increasingly became outsourced to private research contracting companies." These companies were instrumental in developing EM, with the first commercial system developed in Canada in the mid-1990s by Archipelago Marine Research – a company then providing human observers to Canadian fisheries – to address unsustainable harvesting and theft in the 'Area A' Crab fishery in British Columbia (see Ames, Williams, and Fitzgerald 2005). Whilst EM systems have proliferated since, with systems at various stages of implementation across over 100 fisheries worldwide (van Helmond et al. 2020), adoption has been gradual and piecemeal compared with the pace of change imagined. A project manager with Archipelago Marine Research, John, observed that "I've been doing this, this summer will be my 12th year in June. And from the day I started, everybody in fisheries was like, 'Oh, you know, that EM thing, it's just going to blow up next year. Every boat in the world is going to have it.'" (interview, 21.02.23). EM can, in this sense, be seen as part of a wider set of market-friendly environmental interventions which maintain momentum through promising a "socioecological-economic utopia whose realization is always *just around the corner*" (Dempsey 2016, 3, original emphasis), even as they face myriad challenges in the present. These challenges, however, are proving difficult to overcome; Lauren, an officer at the International Fisheries programme at the Pew Charitable Trusts (Pew), noted that advocates are increasingly frustrated that "EM just is not scaling" (interview, 17.02.23).

To understand this, EM should be seen as involving far more than simply the technologies described above (see Figure 13). STS work on data infrastructures has highlighted that the assemblages through which data are produced and circulated are broader and more complex than data-generating technologies and technical infrastructures alone, also comprising a range of socio-cultural components, subjectivities, communities of practice, regulatory frameworks, and data sharing and management practices and infrastructures (e.g. Bates 2018; Bowker 2000; Edwards 2010; Star and Ruhleder 1996). These broader assemblages create tensions and asynchronies between discourses of and

desires for digital and data-driven transformations, and the everyday, situated realities of enacting them.

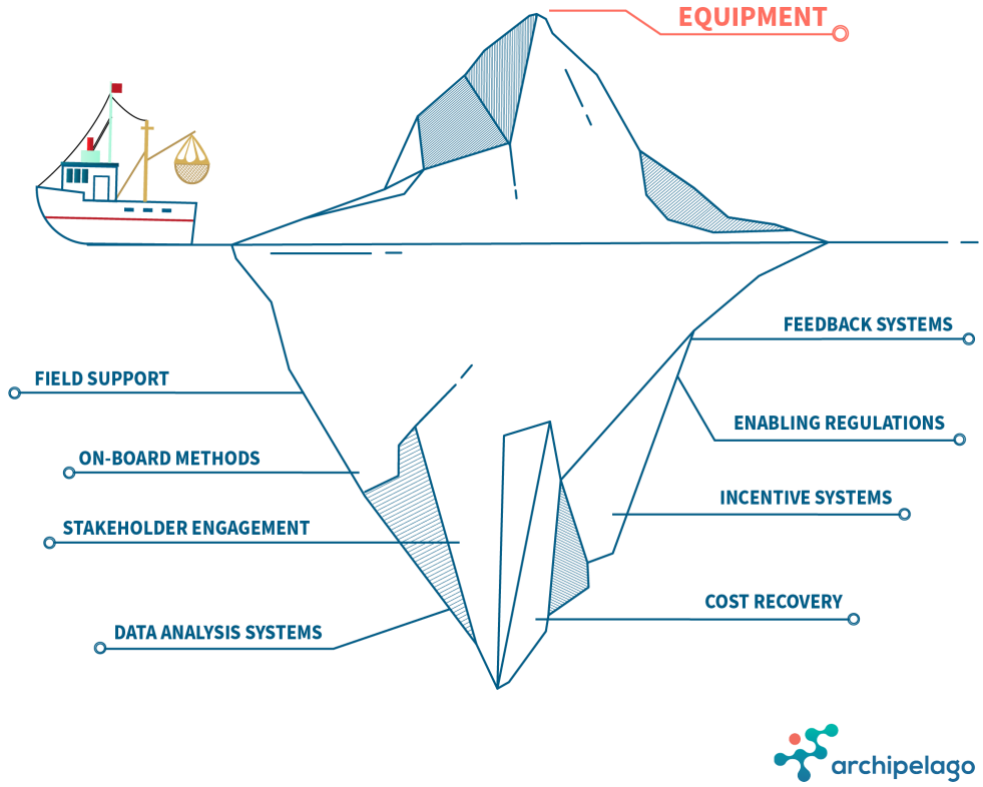

Figure 13 - Equipment is just the tip of the EM iceberg. Reproduced with permission from Archipelago Marine Research.

Jessica Lehman (2020, 166) details the tensions between imaginaries espoused by large-scale ocean observing systems of the ocean as a "friction-free" and "necessarily smooth space for the advancement of science amid environmental crises" on the one hand, and the political dynamics which shape how ocean science is done on the other. Here too, the data that are collected and analysed, how, where, with input and funding from whom, and to what ends, are ultimately determined by the larger assemblage of actors, processes, and financing and regulatory mechanisms involved with EM and the political economies in which they are situated. Moreover, the implementation and functioning of EM is strongly configured by these technologies' material entanglement with their operational milieu on-board boats, with changeable marine environments, and with the heterogeneous human and nonhuman bodies they seek to survey. In the next four sections, I explore these milieu-specific challenges (taken to include the larger assemblage of social processes and contexts

as well as the specific environments EM systems are embedded within) faced by this mode of surveillance, beginning with the upstream dynamics influencing their deployment on boats.

7.3. Upstream: Big Brother is Watching You

The design of EM programmes, and relatedly the distribution of decision-making power, resources, and autonomy amongst fisheries actors are hotly contested. A general trend in the rollout of EM is from voluntary, government or government-industry co-funded trial programmes towards government-mandated, industry-funded programmes (van Helmond et al. 2020), but this trend is uneven, and fishers and fishing companies can be strongly resistant to meeting costs associated with purchasing and maintaining EM equipment and reviewing the data these systems produce. Resistance superficially related to cost is often also entangled with other concerns. As Karen Levy (2022, 7) notes, in industries characterised by mobility and decentralisation, "Geographically distributed and mobile workers […] have historically maintained more independence from oversight than workers centralized in non-mobile workplaces, like factories, call centers, and office buildings." This independence from oversight is valued by some vessel owners and companies as a smokescreen for malpractice, and has led to problems with working conditions and labour exploitation in many fisheries, particularly those in the high seas (e.g. McDonald et al. 2021). Independence can also be highly valued by fishers themselves. As in other industries, attempts to introduce greater workplace oversight with digital technologies can be met with resistance and subversion based on concerns over and experiences of reduced autonomy and control over labour (see Levy 2022).

Opposition from fishers also stems from views that EM is a particularly intrusive example of interventions that have been imposed on them without sufficient consultation or adding value to their operations, and is an expression of mistrust and violation of privacy (see Plet-Hansen et al. 2017; Mangi et al. 2015). At a Fisheries Management and Innovation Group meeting organised by a UK seafood sector actor that I attended, a trawl fisherman illustrated this in a slide with the text, "Big Brother is Watching You," under an image of a CCTV camera. This is, of course, a common trope associated with surveillance technologies. As John, the Archipelago project manager, observed, "blanket statement: nobody wants to be watched,

ever. It doesn't matter what your industry is. You know, cameras are creepy. Full stop" (interview, 13.02.23). This is not always the case - in some contexts, being watched can offer a sense of security, for example. However, as Jordana Wright and colleagues (2014, 97) observe, who feels secured by or benefits from such technologies depends on relations of power and trust between those on either side of the "surveillant gaze." Fishers voice concerns about EM not always or necessarily to reject these technologies, but rather, to demand greater control over the purposes and terms according to which they are watched and governed. This is articulated, for example, in calls for industry-led or co-managed EM programmes built "from the wheelhouse up"[56] and in greater willingness to accept and pay for EM programmes with certain objectives but not others. Lauren from Pew explained:

> "if it's scientific data collection, the fishing sector express that they're happy to pay for it, or not happy, [but] they will pay for it. If it's for compliance purposes and you're going in and looking at that data to figure out if they should be fined or if the fishery should be closed, they're not as tolerating of those costs" (interview, 17.02.23).

As George Cusworth and colleagues (2023, 3–4) note of controversies in the design of environmental metrics, at issue here are deliberate efforts by actors to "influence the metrological regime under which they live," knowing that the design of these programmes "will shape the worlds they have to inhabit." These efforts involve cultivating what I term 'procedural friction' whereby fishers and the fishing industry more broadly seek to slow down the implementation of EM technologies or to shape their remit in ways that are acceptable or favourable to them. Through formal upstream negotiations and procedures, they challenge the normative imperative of "seamlessness and unhinged flows of data" (Aula 2019, 3) espoused by, for example, environmental NGOs, fisheries managers, and tech companies. This is a source of frustration to those who contest the degree to which the fishing industry is (or should be) able to influence the conditions of its own surveillance. Sandra, a seabird bycatch programme manager, expressed that, owing to the entrenched culture of secrecy noted above, "it's kind of funny because there's not really any other industry where you can get away with such a lack of oversight, if you were doing anything else then you would be

[56] This was expressed repeatedly by panellists at a Fishermen's Roundtable on Electronic Monitoring hosted by the non-profit EM4Fish (27.10.20). For a recording, see https://www.youtube.com/watch?v=LYChaFh8aI0&t=1387s (last accessed: 23.07.23)

inspected, but with fishing it just feels like it's acceptable or people feel it's acceptable" (interview, 24.02.2021). Kevin, a technical officer from a fisheries monitoring company, asserted to me that industry-led EM programmes were "like the fox guarding the chicken coop" and that privacy and cost concerns were a "non-excuse" from actors seeking to "hide their dirty little secrets" (interview, 03.03.23).

However, as I turn to in the following section, the degree to which fishers and the fishing industry are able to affect the conditions of their surveillance – and, relatedly, the degree to which EM is able to fulfil a promise of greater transparency in fisheries governance – is not limited to these upstream dynamics. New sources of friction follow from the EM technologies themselves when they are deployed on-board boats, which are liable to glitching in ways that present opportunities for strategic interventions aimed at creating 'selective transparency.'

7.4. On-Board: glitchy hardware and fisherly sabotage

Despite being intended to fulfil and (partly) replace the role of human observers, whose material requirements (e.g. space, safety, salaries) can limit monitoring efforts, EM systems are not an *immaterial* replacement – they become part of the existing infrastructure of fishing vessels and are materially affected by the conditions encountered on-board these vessels. These material relations influence "the cost in time, energy, and attention required simply to collect, check, store, move, receive, and access data" (Edwards 2010, 84), thus generating data frictions specific to this milieu. When I visited an EM trial programme monitoring seabird bycatch by gillnet vessels in the UK, funded by a UK energy industry actor and delivered by a private fisheries monitoring company, Kevin, a technician from the company, offered some insights into these frictions. The first of these stems from the materialities of fishing vessels, which are heterogeneous spaces not designed with EM technologies in mind. Skilled improvisation is required to install hardware within the constraints of existing on-board infrastructure like masts, available surfaces, and electrical systems, so that video is captured of the right things, sensitive equipment stays dry, and power supplies are reliable (see Figure 14). Kevin (interview, 03.03.2023) explained that the

first hour of the installation process is usually spent “scratching your head wondering how you’re going to make this happen” before even unpacking the equipment.

Figure 14 - 1. A GPS unit (left) and camera (right) mounted to the vessel mast. 2. Camera facing the net hauling. 3. System display houses in the wheelhouse. 4. System display showing both camera angles. 5. Computer stowed beneath the dashboard. 6. Swapping hard drives. Author’s images.

This is often a trial-and-error process. Reviewing a series of EM trials, Aloysius van Helmond and colleagues (2020, 177) note that “it can be difficult to position a camera in a way that can enable a wide, clear, and undistorted view of the (fish) sorting area without the risk of water and fish waste splashing up onto the camera casing.” Camera positioning is not the only issue of concern. On one vessel Kevin and I visited, a leak in the roof of the

wheelhouse had caused irreparable water damage to a previous system display, requiring installation of a new one in a different location, with a cotton rag now wedged into a gap in the roof to soak up incoming water. Kevin also described issues with variable power supplies on some of the smaller vessels in the trial, which caused hardware designed for larger vessels with more predictable power supplies to fail. This had required him to replace new, more voltage sensitive systems with older versions that were more resilient, with some grumbling about the morality of the equipment provider who "swore black and blue" that the new systems would work.

These idiosyncratic examples illustrate a wider issue, that EM hardware is prone to 'glitching' through exposure to the variable conditions encountered on-board boats and at sea. Of recently reviewed EM trials in Europe, 11 out of 15 reported technical failures and loss of data (Helmond et al. 2020; see also Eric Gilman et al. 2019). Alongside the abruptness of outright failure, the effects of saltwater and humidity on hardware necessitate periodic maintenance, repair, and replacement, and fog, rain, sunlight, cloud cover, fishing at night, and salt on the camera casing all affect the clarity of video footage collected by the cameras. Summarising the effects of these conditions, Barry, an Australian government conservation policy advisor, explained "weather is not good for doing these things, basically" (interview, 13.02.23). These glitches, whether caused by technical malfunction or material-meteorological factors, are not infrequent abnormalities in the otherwise smooth operation of EM systems. Rather, they can be thought of more as what Agnieszka Leszczynski and Sarah Elwood (2022, 365) term "nonanomalous anomalies": glitches which are part of the 'normal' imperfect functioning of these systems.

The significance of such glitches extends beyond simply their existence; they are sometimes deliberately nurtured into being and engaged with as a "tactical point" (Barry and Gambino 2019) – a strategic juncture for disruptive intervention in a larger infrastructure – by fishers seeking to interrupt flows of data about on-board activities. Interviewees working to implement EM argued that fishers often strategically create discordances between on-board realities and recorded data. These actions can be generic – as Eric Gilman and colleagues (2019, 919) note, EM systems "require active support from fishers", and this can be withheld – or can be targeted at specific events, like seabird bycatch, which fishers wish to

occlude from recorded data. Barry, for instance, explained to me that in an EM programme in Australian longline fisheries "there was a practice of shaking the birds off before they came on board the boat" into view of the camera, because recorded birds impacted their fishing licences. More covert interferences included "issues with tampering with the lens, just spraying salt water onto it and the salt settling" (interview, 13.02.23). Kevin mused that he thought fishers sometimes hauled their nets deliberately into the sun "just to screw us" and generate obfuscating glare in the footage (interview, 07.03.23). Moreover, several studies note the frequency of people obstructing camera views on-board, particularly on smaller vessels where space is limited (Eric Gilman and Zimring 2018; Eric Gilman et al. 2019; Helmond et al. 2020). In instances like these, it can be challenging to isolate deliberate sabotage from a changeable marine environment and chaotic on-board workplace; a boundary which is liable to exploitation when obvious acts of sabotage are penalised by 'return-to-port' orders or other sanctions (Liam, interview, 07.03.23).

In the previous section we encountered procedural frictions whereby industry actors seek to formally shape the scope of surveillance regimes in their interest. Here we see that these upstream negotiations are not the only tactical point for intervention and that, once implemented, marine materialities and technological limitations – both of which fishers work with to their advantage – complicate EM's delivery of transparency. Or, framed slightly differently, transparency itself comes into question as a sufficient way to understand what EM currently delivers. By accepting EM systems onto boats and as part of the management of a fishery, either voluntarily or because of top-down mandates, in full knowledge that their intended effects are not a foregone conclusion, transparency can be *performed* while a more selective, curated version of events is provided. Without seeking to assert or generalise the intentions of fishers, it nevertheless becomes apparent here that EM, as Leszczynski (2019, 190) writes of digital platforms in cities, "may beget an array of possible outcomes that remain shapeable by mundane tactical interventions in the [digitally] mediated present." Through such interventions, industry actors engage in what I term 'selective transparency,'[57]

[57] While I have not found references to this notion in literatures on (environmental) governance, in her book 'On Photography' (1977), writer Susan Sontag refers to photographs as an artistic form in terms of 'narrowly selective transparency' to question the relationships between these representations and reality through reference to the frames imposed by the photographer. This is somewhat relevant here, especially in terms of the relations between the images produced by EM cameras and the on-board realities they purport to truthfully represent.

whereby they perform conformity to managerial expectations and best practice by accepting EM as part of their workplaces and practices, even as they work with the frictions and glitchiness of EM technologies to strategically undermine the governance transformations they promise.

7.5. Downstream: things that are hard to identify

> "The video footage isn't evidence of anything until somebody looks at it. It's only footage that's been viewed that's of any use to any system. The fact that you collect footage is irrelevant, you might as well collect baseball stamps […] in reality I suspect there's going to be very little appetite to actually audit that but they [fisheries managers] are sitting there saying well we're very effective because we've got this footage, but as I said it's absolutely irrelevant." (Barry, interview, 13.02.23)

Thus far, we have seen that the rollout of EM and the intended functioning of these technologies are complicated by processes which affect, broadly, the *collection* of data. However, as Barry, the Australian government advisor, observes above, this is only a small part of the processes by which EM informs fisheries governance, which further involves people viewing, analysing, classifying and making decisions based on this data. Writing about classification systems used in biodiversity databases, Geoffrey Bowker (2000) identifies a series of things which are hard to classify, or which do not get classified, owing to their singularity or the lack of interest they attract. He observes that "things which cannot be described easily and well get ignored, and so receive an ever-decreasing amount of attention," (ibid, 650) whilst things which "do not lead to spectacular science or good funding opportunities" (ibid, 655) are often simply not classified and tend to get rendered invisible. In this section, I expand on the concept of 'selective transparency' – showing how certain things are more likely to be identified and classified through the ways in which EM data is currently reviewed, and certain things, like seabird bycatch, are less so. I begin with an illustrative 'walkthrough' of the EM data review process.

After visiting the EM trial described above, I joined Kevin and two other employees of the company conducting the trial, Liam and Chris, online for a demonstration of the data reviewing process. They were using 'FishVue Interpret Pro' – a widely used EM data review

software application developed by Archipelago Marine Research[58] – to identify seabird bycatch per unit of fishing effort (i.e. birds per metres of net or fishing time). The FishVue interface displays the video footage from on-board cameras to the right of the screen, and information about the fishing trip to the left, including a map, time and date information, vessel speed, and functionalities for annotating data with time- and location-stamped information about fishing activities observed in the footage. For example, when a seabird appears in the video footage, the reviewer can make an annotation of a 'catch item,' using a dropdown menu to input information about species, fate, condition, and life-stage (Figure 15).

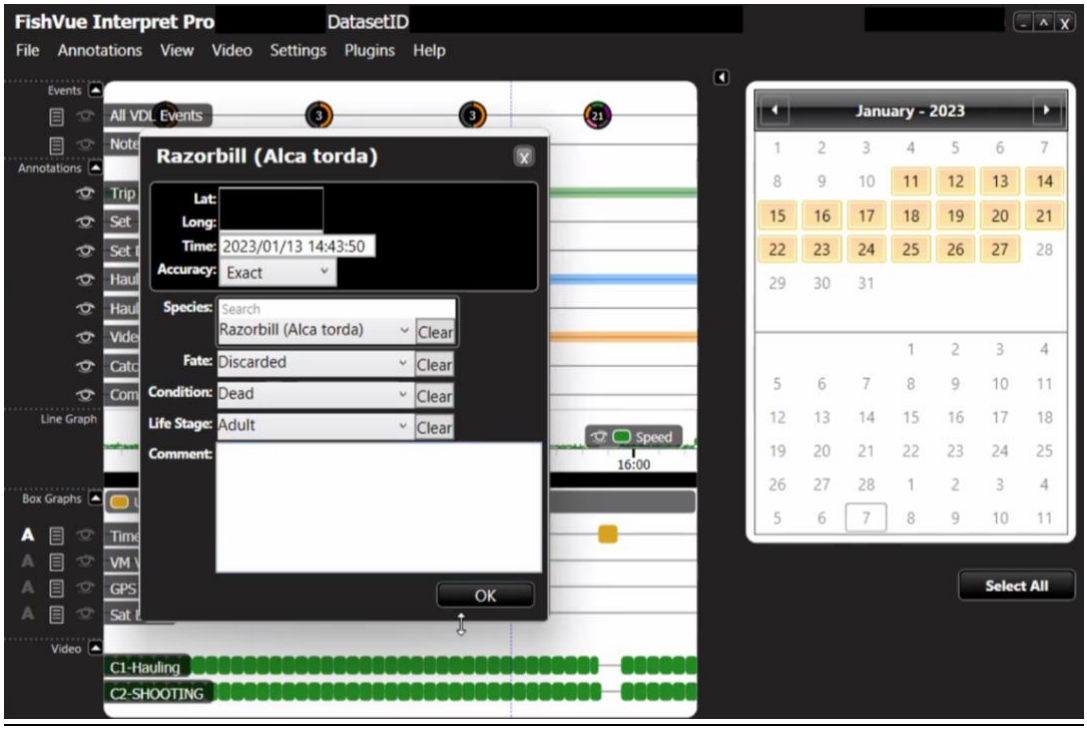

Figure 15 - A dropdown menu for annotating a 'catch item'. Author's image.

This catch item then appears as a purple 'CI' icon on both the graph (when a bycatch event happened) and the map (where it happened) and, when clicked, displays the video footage corresponding to the time of the annotation. This is displayed in Figure 16, with the CI icons ringed in red. Fishers, who were remunerated for their voluntary participation in this trial, were asked to hold the birds up to the camera to assist in identifying the species caught.

[58] FishVue Interpret Pro is described by Archipelago Marine Research as "the most trusted and proven EM data review tool in the world…utilized to review more EM fishing days per year than any other data review application." See https://www.archipelago.ca/products/fishvue-interpret (last accessed 23.07.23)

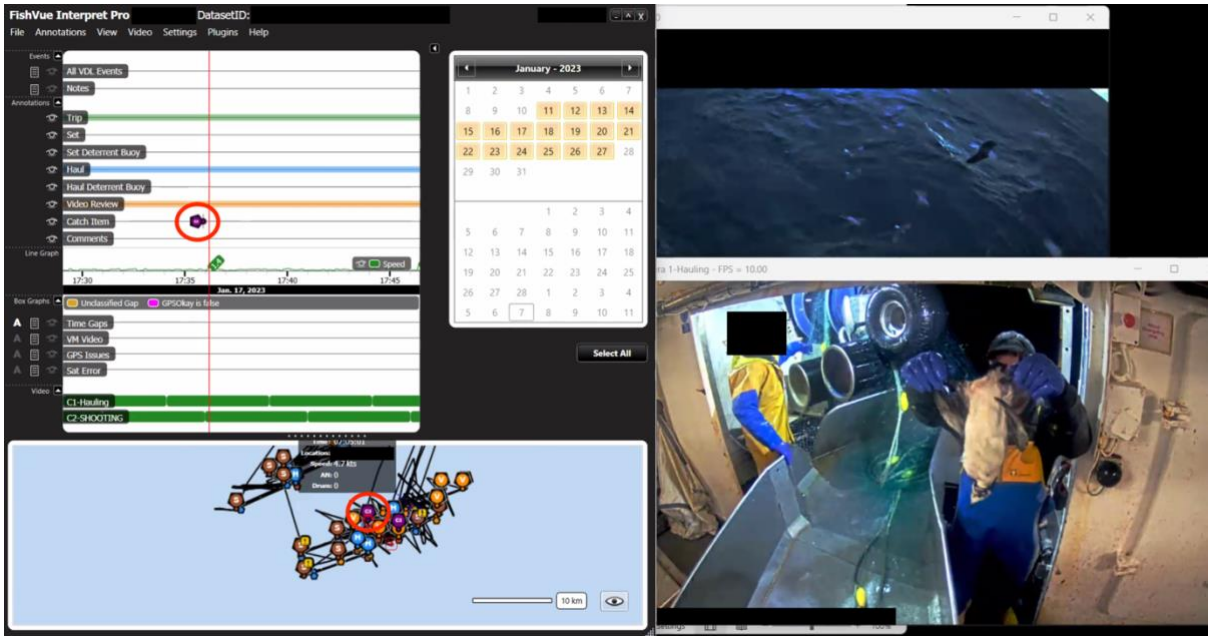

Figure 16 - A dead seabird in the EM footage, displayed as a 'catch item' in the graph and map. Author's image.

At the end of the reviewing process, the graph and map should show each time fishing gear was set and hauled, the length of the fishing trip(s) overall, and a characterisation of each instance of seabird bycatch. Figure 17, for example, displays the number and duration of sets and hauls over the course of two separate fishing trips in a week, and two CI icons corresponding to two seabirds caught.

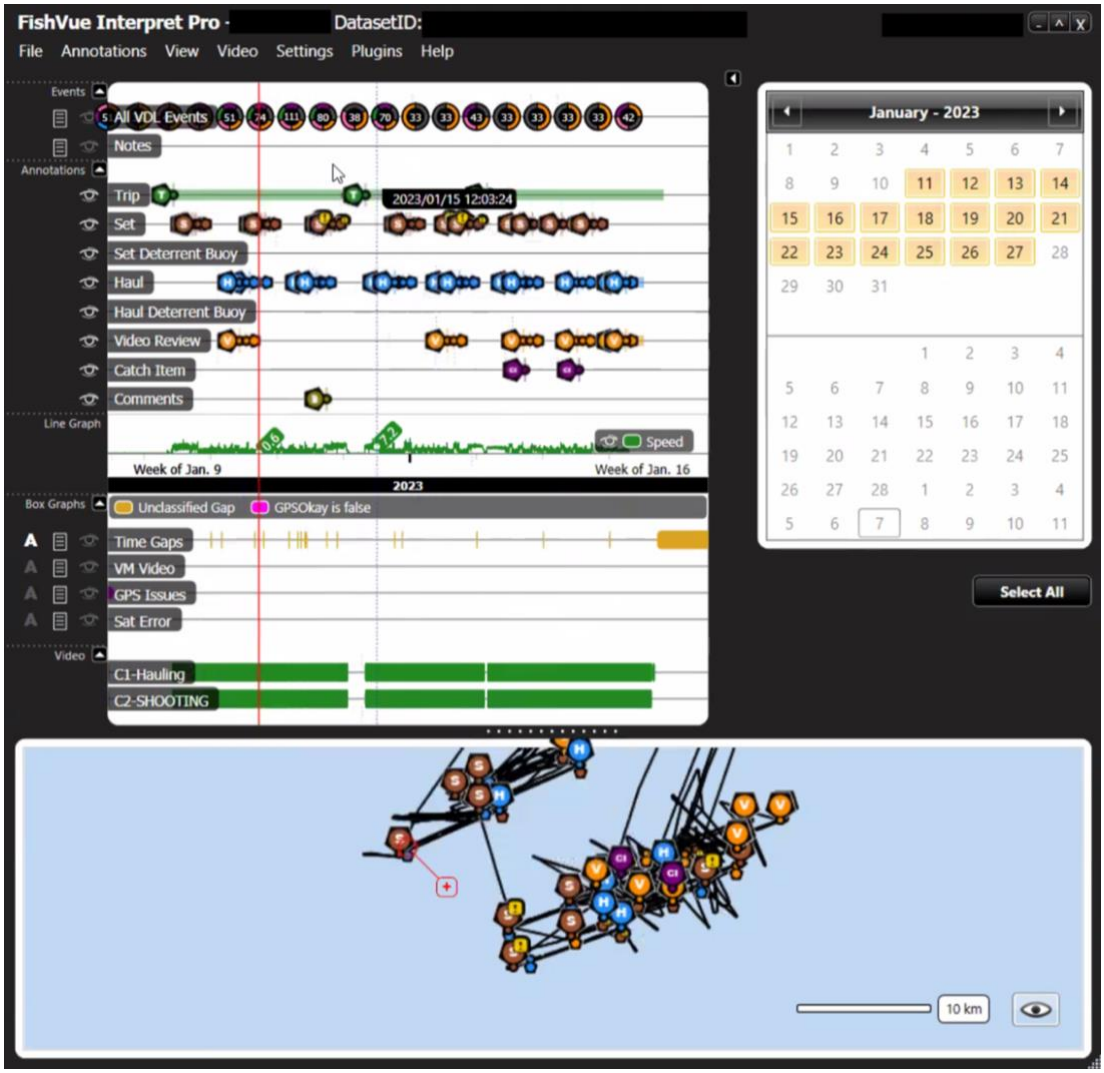

Figure 17 - A fully annotated EM dataset. Author's image.

In this trial, 100% of the EM data was reviewed to identify all instances of seabird bycatch. This represents an ideal scenario for fully documenting seabird bycatch from an on-board perspective. This is not the norm, as I describe below. However, even here, several potential sources of friction can constrain this documentation. As Eva, an associate with the International Fisheries programme at Pew, explained, much of a fishing trip is "dead time" when a boat is motoring from a port to the fishing grounds and back, travelling between fishing grounds, and during much of the fishing time itself when little of interest is happening (interview, 17.02.23). In the above example, the two most important events to observe (when there was a dead seabird in the frame) occupied some tens of seconds in tens of hours of footage. Indeed, the infrequency of seabird bycatch events in the context of overall fishing effort belies their significance in driving seabird population declines. In longline fisheries, for example, bycatch of seabirds can be as low as 1 bird per 100,000 or 1,000,000 hooks set

(Commonwealth of Australia 2018; Eric Gilman et al. 2016). The effectiveness of EM review for identifying these events can thus be warped by the phenomenological characteristics of the task at hand, which can be extremely boring. In Gavin Smith's (2004, 376) ethnography of CCTV control rooms, he identifies tedium, tiredness, wandering attentions, "the difficulty of effectively monitoring up to fifteen television screens simultaneously," as well as lack of motivation and satisfaction as everyday features of operators' work. EM specialists are likewise aware of boredom, or "human constraints such as limits of analyst concentration and fatigue" (Pierre et al. 2022, 31), as a factor affecting the outcomes of data review. As Barry pointed out:

> "having some poor kid look at six cameras on screen for hour after hour, you know, you can imagine that the capacity for not paying attention when you're looking at something that's boring as all heck and pressing fast forward to get through that 6-month reel of footage [is significant]" (interview, 13.02.23).

Those designing and funding EM programmes, however, are less concerned with these human attentional glitches than with the costs of review. As review can constitute up to 60% of the costs of an EM programme, often met by the fishing industry, there is an incentive to reduce review rates significantly below 100% (Michelin et al. 2018). Fisheries consultants Johanna Pierre and colleagues (2022, 43) explain that, in this context, "the key trade-off becomes data needs versus available resources (budgetary and/or human, in the form of analyst hours)." Within this calculus, common events whose frequency can be more accurately estimated with lower review rates are favoured over rare and spatially unpredictable events. Effectively monitoring seabird bycatch, for instance, can require near-total review because extrapolating its frequency from a small subset of the data is difficult (see Pierre et al. 2022). As Nathan, a working group convenor with the Agreement on the Conservation of Albatrosses and Petrels, suggested, those involved in the design and funding of EM programmes can therefore take the view that "seabird monitoring will cause too much kind of workload […] and sometimes it can be a strategy to get that delayed" (interview, 20.02.23). Illustrating this with reference to the widespread problem of seabirds colliding with the warp cable on trawler vessels, John explained:

> "it's just not financially plausible because there's no way of knowing, like there's a lot of vessels that do 12-hour tows. If you turn that into ten times speed playback, you've got 1.2 hours of sitting there watching, waiting for the random event of a bird whacking into the trawl wire and then falling dead into the ocean […] It's a problem all over the world and I think people would be quite interested to look into it if it was affordable. But it's not. So nobody does [...] your one dead seabird is worth a fortune in labour" (interview, 21.02.23).

To summarise, although instances of seabird bycatch are *recorded* in EM data, they are i) sometimes not identified because of distorted or obscured views and the attention required to spot them, ii) hard to identify because of the rarity with which they appear on boats in space and time, and iii) because of this, there is minimal appetite from a financial perspective *to* identify them amongst those deciding the scope of EM programmes. Such events cause data friction, by increasing the costs associated with data review, and this friction is rationalised into a justification for excluding them from the remit of EM programmes. Seabird conservationists – who, as we saw in Chapter Five, have limited sway over decisions made in fisheries management organisations – are concerned that this "rare event problem" (Barry, interview, 13.02.23) means that "seabirds will be missed off the list"[59] in the design of future EM programmes.

This helps to specify what kinds of entities or events might be in/excluded in the pursuit of selective transparency with EM. Bowker (2000, 655) suggests that "If certain kinds of entities and certain kinds of context are being excluded from entering into the databases we are creating […because] they are singular in space and time, then we are producing a set of models of the world which […] generally converge on descriptions of the world in terms of repeatable entities." The implications of this here are, I suggest, as follows. If rare events are being unintentionally and deliberately occluded from what is monitored with EM, and we see these rare events as signals of deviance – that sometimes vessels are not catching what they are supposed to, or not complying with regulations – then what is produced is more like a rose-tinted lens on fishing activities than the effective, efficient, and democratic governance,

[59] This was an observation made during a presentation by an RSPB bycatch programme manager during a discussion of EM at the World Seabird Conference 2021.

and improved performance based on reflexive adaptation to surveillance, that the drive to transparency in environmental governance promises (cf. Turnhout et al. 2014).

7.6. Downstream: the allure of algorithms

My basis for making this claim is strengthened in this penultimate section by turning to a recent development seen as key to scaling the implementation of EM. Reflecting a wider turn to algorithms for addressing environmental governance challenges (Adams 2018; Bakker and Ritts 2018; Nost and Colven 2022), conservation NGOs, government agencies, and technology providers are increasingly foregrounding algorithmic solutions to EM data review. The allure of machine learning and artificial intelligence algorithms (hereafter AI) is that they could automate data review, facilitate full review of all EM data at lower cost than human reviewers, and enable a range of real-time governance interventions (Kay and Merrifield 2021; Rizwan Khokher et al. 2021; Qiao et al. 2021). Maoying Qiao and colleagues (2021, 33), for instance, posit that in the near future, "the automation of vessel catch and bycatch identification will operate in real-time, allowing immediate logging of catch data and the rapid response by regulators to unwanted interactions with endangered species." For seabird bycatch specifically, AI appears to offer a pathway to overcoming the rare event problem identified in the previous section. Instead of having to contend with issues of analyst boredom, costs, and subsequent resistance to monitoring, "you could just run the data through a computer, and it would come back and give you every single bycatch event," as Sandra, a seabird bycatch programme manager explained (interview, 24.02.21). AI here, as in other contexts, is invested with the promise of overcoming the need for trade-offs based on human constraints by "extending the threshold of human perception and cognition" (Amoore and Raley 2017, 4), facilitating the production of more accurate understandings of fishing activities through EM.

However, thus far, AI trial projects have demonstrated mixed successes with identifying species and fishing activity, often within tightly controlled parameters. An operational model is far from realisation (Kay and Merrifield 2021; Rizwan Khokher et al. 2022; Qiao et al. 2021). The reasons for this are multiple, and how the speculative promise of AI in this context interfaces with the difficult realities of enacting workable models offers

fertile ground for future research. In this section, however, I focus specifically on the ways in which different actors engage with this technology presently by controlling flows of data in ways which both assist and hinder its further development. In doing so, they affect the rollout of EM and its delivery of transparency as indexed to the development of AI.

Automating EM data review requires algorithms to learn to identify and classify what is in EM data through large training image datasets of EM images with labelled boxes around objects of interest. In simplified terms, having seen enough labelled images of a given object (such as a species of fish or seabird), the AI should be able to identify that object in an unlabelled image. However, this training image data is difficult to come by, primarily because of constraints on its accessibility and use. EM data are governed by data agreements between vessel owners, management authorities, and service providers, which determine conditions of access, sharing, confidentiality, and use (e.g. Michelin, Sarto and Gillett 2020). Currently, use of data to train AI falls outside of the terms of most of these agreements and access for this purpose is negotiated separately (Kay and Merrifield 2021). Whilst governmental and corporate actors want to develop AI for EM data review, an issue they face in doing so is, as John explained, that:

> "none of the EM companies own data. So now we have a very kind of lawyer catch 22. So how do I develop AI to detect dead seabirds? Because I don't own the data, and in most cases I have permission to analyse the data in order to deliver on my contract but I don't have permission to then also use it to develop artificial intelligence." (interview, 21.02.23)

Open access training image datasets, which are commonly used to train AI models for numerous purposes,[60] could accelerate the development of AI for EM data review (Robert, interview, 16.02.2023). However, fishers and vessel owners can be reluctant to agree to publicly sharing EM data because of its commercial value and concerns about privacy and publicity. Interviewees described particular resistance towards sharing image data with the potential to cause reputational damage, such as images showing dead birds, marine mammals, and sea turtles. Such images, as discussed in the previous chapter, have the

[60] See the COCO (https://cocodataset.org/#home) (last accessed: 25.09.23) and ImageNet (https://www.image-net.org/) (last accessed 25.09.23) datasets for examples.

capacity to elicit strong sentimental responses amongst particular audiences. As Robert described, “That’s kind of their biggest fear…that, you know NBC News is going to go in there and say, ‘look, you're catching all these seabirds,’ and the brand will get damaged” (interview, 16.02.23). In instances where access and sharing agreements for EM image data have been secured, such as for The Nature Conservancy’s ‘Fishnet’ – an open access dataset with some 150,000 annotated images – images of bycatch have been purposefully removed from the original dataset in response to fishing industry concerns (Robert, interview, 16.02.23). Ironically, seabirds’ capacities to function as sentinels of sentiment impact negatively on their capacities to function as sentinels of the ecological harm done by certain kinds of fishing, causing them to be deliberately hidden from view in these emerging monitoring assemblages. Semi-jokingly, John commented that in one of his company’s projects trying to identify seabirds using AI, “I said, you know, we just need to kill a few hundred more birds and, like, we'll be somewhere […] We don't have enough stock footage of dead birds, which is a really weird thing to say, but it’s a problem” (interview, 21.02.23). As a result of this selective in/exclusion of certain kinds of image data, Eva, the associate from Pew, identified that:

> “you run into issues about data confidence. What are these algorithms being trained on? Can we say that it's smart enough for scientific purposes and that it's trustworthy enough for us to include this for our management decisions or our stock assessments? And then you run into issues of data privacy. Is this now proprietary data that they're collecting that goes into government issue fleets only or like can this be widened out broadly? It's a chicken and egg issue of can we get enough interest to build it up so it is cost-efficient, but how can the government or industry feel comfortable enough actually giving money for those things to be developed?” (interview, 17.02.23)

Industry actors, then, seek to control flows of data in their interests by intentionally creating friction constraining the accessibility of data in general (e.g. resisting open access databases while accepting certain data uses by service providers under data access agreements) and the accessibility of certain *kinds* of data (e.g. images of rarer, potentially reputation-damaging, events compared with images of everyday practices). This friction is a way to deliberately cultivate constraints on the capacities of AI and who stands to benefit from its use, creating AI models that are, presently, glitchy and imperfect somewhat by design. Whilst

some of these issues can be addressed, for example through new data sharing agreements and more powerful future algorithms, an enduring problem is likely to be that, by virtue of its learning processes, AI is structurally less capable of identifying species and events it has seen fewer examples of (Rizwan Khokher et al. 2022). This different manifestation of the rare event problem described in the previous section leads to similar outcomes in terms of selective transparency, maintaining the relative invisibility of seabird bycatch and other uncommon events to decision-makers. If this perpetuates from trial AI models into fully operational ones, it could lead to systematic underestimation of the impacts of fisheries on non-target and rarely-caught species, reproducing rather than overcoming the issues associated with human review.

7.7. Conclusion

This chapter has considered the reconfiguration of fisheries monitoring with electronic monitoring (EM) technologies, particularly as this pertains to monitoring seabird bycatch. As I have stressed, this reconfiguration is still taking shape. EM is "a technology already with us and a work-in-progress, laden with promise for what it might become," as Jack Stilgoe (2018, 26) writes of self-driving cars. The promise of EM to increase the transparency of fishing activities and the effectiveness of fisheries governance aligns it with a range of recent 'Smart Ocean' approaches. My analysis of EM has diverged, however, from existing analyses of these approaches in its specific focus on the glitches and frictions implicated at three different stages in the operation of EM: upstream of its implementation; in the on-board context of its deployment; and downstream where the data these technologies generate are analysed and actioned. This focus responds to recent calls from digital environmental geographers to rethink "majoritarian narratives of the technonatural present"[61] (Searle et al. 2023, 3), through the affordances of the glitch. It also emerged organically from my research; the analytical import of glitches and frictions became evident from their persistent recurrence in the discussions I engaged in about these technologies and my observations of their functioning in practice. In this conclusion, I suggest two ways in which this matters for our understandings of 'smart' or 'measurementality'-based configurations of ocean governance.

[61] Most notably, the dominant narratives of 'techno-hysteria' and 'techno-utopia' that I identify in sections 2.4 and 3.2 of Chapter Two.

The first of these is that glitches and frictions attune us rather differently to the effects that digital monitoring technologies have in the world, and specifically in ocean governance. Engagements with these technologies through the lenses of "erosion, breakdown, and decay, rather than novelty, growth, and progress" (Jackson 2014, 221) have become increasingly commonplace amongst digital geographers, media studies and critical data studies scholars (see Amoore 2020; Bates 2018; Pink et al. 2018). This has yet to percolate into research on ocean governance. My proposition is that if scholars are to explore in greater detail what Smart Ocean transformations and their effects *are* rather than simply engage in abstract celebration or critique of them – as Lauren Drakopulos and colleagues (2022) enjoin us to do – then glitches and frictions are an unavoidable and important part of these explorations. This matters because it allows us to understand that the effects of these transformations are far from pre-determined, they are configured by the (deliberately) imperfect functioning of digital technologies within the milieux in which they are deployed and the strategic actions of actors seeking to shape these transformations in their interests. This is an area where the broadly distinct engagements with the ocean from literatures in political ecology and in engagements with the ocean as a dynamic, voluminous, epistemologically challenging space might usefully come together. By their own admission these latter engagements are often concerned with thinking *with* rather than *about* the ocean, but I have found the kinds of 'milieu-specific analyses' developed in this work to be helpful in specifying the marine-milieu-specific glitches and frictions at work with EM (Jue 2020; see also Helmreich 2011; Steinberg and Peters 2015). There is scope for expanding these conversations in future work to broader analyses of Smart Ocean transformations.

The second implication concerns a different understanding of transparency and measurementality in environmental governance that has emerged from this chapter. I have mobilised the notion of 'selective transparency' to describe how the ideal of transparency can be performed by different actors even as it is strategically undermined in practice through cost-saving, limited data sharing, and the deliberate cultivation of glitches. When transparency is indexed narrowly to the deployment of environmental surveillance technologies and the generation of more data with them, it can theoretically be 'achieved' whilst nothing much changes at all. This is not to affirm transparency as a 'good' governance

ideal undermined by deviant practices. As Turnhout and colleagues (2014, 583) observe, “the seemingly neutral tasks of measuring and counting in order to achieve transparency actually provide the basis for centralized control, coordination, and exchange.” Nor is it simply to challenge the idea that more and better data straightforwardly leads to transparency, a vein of critique which is well established (see e.g. Nost and Goldstein 2021). Rather, it is to suggest that future work might more systematically engage with how measurementality is configured and engaged with by those who become the targets of interventions aimed at increasing transparency. In doing so, a more complex picture of the knowledge regimes and power relations implicated in environmental surveillance and their potential to be disrupted might emerge, alongside more situated understandings of what specifically is in/excluded from view and from the scope of governance interventions as a result.

Chapter Eight

Conclusions

8.1. Introduction

> "That, instinctively and subliminally, is what these birds mean to us, voices from the interior of self and ocean, bringing to consciousness those unseen worlds, making apparent what would otherwise be hidden" (Nicolson 2017: 4)

In this concluding chapter, I summarise the main arguments, conceptual developments, and contributions made in this thesis. My aim has been to develop a novel approach to environmental sentinels whereby new insights into the more-than-human collectives, technologies, and practices implicated in knowing and governing the Anthropocene's turbulent ecologies come into focus. I have pursued this through an empirical account of how seabirds become and act as sentinels in contemporary scientific and environmental governance practices, focusing particularly on albatrosses and the problem of seabird bycatch in commercial fisheries. My inquiry was guided by four research questions roughly corresponding with the empirical chapters of the thesis: i) *how and why have seabirds become sentinels*; ii) *how are seabird sentinels used to govern ocean space and with what consequences*; iii) *how do sentiments shape how seabirds act as sentinels; and* iv) *how are the promises of digital ocean governance complicated in practice and with what consequences for seabirds and marine ecologies?*

My approach to these questions was guided by the conceptual framework and methodology developed in Chapters Two and Three. The main conceptual development proposed in Chapter Two was **sentinel geographies**, a novel field of geographical inquiry entailing attention to the contexts of motivation shaping how and why particular environmental sensing and governance practices take hold and with what effects, an understanding of these practices as more-than-human, and an approach to environmental sentinels in terms of devices, collectives, and practices. I demonstrated how a focus on animal sentinel built on existing work on animal sensors and other similar configurations of nonhumans, proposing two additional concepts – **operational sentinels** and **sentinels of sentiment** – to build on extant social scientific engagements with sentinels and better describe their diverse operation. In the Introduction, I suggested that a focus on seabirds also built upon these engagements by drawing our attention to the more expansive geographies,

interconnected human and environmental systems, and temporalities at play in their roles as sentinels.

This focus has dictated that seabirds have been as central to this thesis as sentinels. To reduce seabirds to a tool for elaborating on sentinel geographies would be to reproduce some of the more troubling logics seeing them operationalised in the governance of ocean space. Before proceeding then, it is important to reiterate the underlying issues at stake here. Namely, that ocean ecologies are undergoing rapid change, and continue to be exploited at a pace and scale which is driving the disappearance of many beings and ways of life from this world. This is the turbulent Anthropocene ocean context within which seabirds become sentinels. As Frédéric Keck (2015, 166) writes in the very different context of intensively farmed chickens used to signal avian influenza: "For sentinel birds, it is a dirty death; but for humans who posted them, it is a clear signal." I enjoin scholars to take up further investigations of environmental sentinels but in doing so, to keep in mind this relationship between signalling and dying, or failing to live well, through which sentinels come into being.

8.2. Summary of chapters

I began the empirical analysis of this thesis in the company of British zoologist Lance Tickell as he studied the wandering albatrosses of South Georgia in the late 1950s. By censusing these birds and making them legible as a population, changes in their numbers could be registered through subsequent years of monitoring. I suggested that studies like Tickell's laid the groundwork for an understanding of seabirds as cost-effective samplers of the marine environment which began to take route from the late 1970s onwards. I approached this as a strategic decision by seabird scientists seeking to direct more funding and interest towards their work, and as an outcome of the wider geopolitical contexts shaping marine research. Seabirds did not easily yield to this new framing. I showed how studies were beset by difficulties in inferring information about the marine environment from seabirds' bodies and behaviours, and how researchers embraced new 'bio-logging' devices to collect environmental data directly with the birds when these became available in the 1990s. This led to a new framing of the birds, and other animals used in similar ways, as 'platforms' for

oceanographic data collection. Populations, samplers, and platforms are all evidenced in contemporary references to seabirds as sentinels – one has not simply replaced its predecessor. In tracing the historical emergence of these different framings my intention was to trouble a common refrain amongst scientific accounts which suggests that animals simply *are* good sentinels, as if this were an inherent quality, by showing *how* and *why* it is that they *become* so within particular collectives and as a result of specific and changing scientific practices.

The notion of animals as platforms is being extended beyond knowing ocean spaces and ecologies towards governing them in new ways. The Ocean Sentinel project discussed in Chapter Five promised "to use animals as platforms to *make research operational,* especially for large-scale surveillance" (Weimerskirch et al. 2020, 3007, my emphasis). I argued that, in doing so, Ocean Sentinel not only makes the research approach of wildlife biologging operational, but also operationalises animal sentinels by enacting what I termed "on-bird surveillance." I mobilised the concept of operational sentinels to distinguish this use of animal sentinels from the ecological concept of sentinel species which geographers and other social scientists have engaged with, and to situate these sentinels in relation to what Andrew Lockhart and colleagues term "operational ecologies." This term denotes "emerging and experimental sites of environmental enclosure, control, intervention and exploitation, enabled by the capacities of [digital] technologies, designed to fix, manage or transcend contemporary environmental turbulence" (Lockhart et al. 2023, 4). The operational ecology at issue here was configured around rendering illegal fishing activities visible to marine enforcement agencies, and amenable to control in the interests of both conservation and securing territorial boundaries in marine space. I suggested that the project's approach expressed a mode of 'cyborg anatamo-politics,' which entails turning animals' bodies into technologies for dealing with environmental turbulence (cf. Barua 2021), captured by the comparison of albatrosses to surveillance drones for enacting security. I nevertheless suggested that this was insufficient to understand how this mode of governance operates, because it is albatrosses' liveliness, not their quasi-machinic properties, which shape the functioning of this approach. In showing how seabirds were used to govern ocean space through this project, I further contrasted it with two related approaches: the mapping of seabirds' overlaps with fishing effort in cartesian space; and dynamic ocean management

approaches which depart from spatiotemporally fixed approaches to marine monitoring and management and propose more fluid, responsive alternatives.

I then turned to the consequences of this way of governing with seabirds. I showed how Ocean Sentinel inaugurated potential risks to the animals involved and was criticised by researchers and conservation practitioners who were concerned about these risks and the implications of a surveillance-based model for their relationships with fishers and fisheries management organisations. In doing so, I also questioned the naturalisation of surveillance as an appropriate marine governance technique and suggested a set of developments in research and practice to help conceptualise and govern such approaches as they become more widespread. These were: the need for ethnographic research into the experiences of those subject to new forms of animal-based surveillance (and conservation surveillance more generally); the need to develop context-specific frameworks governing the use of these methods; and the need to retain more affirmative perspectives on uses of wildlife tracking and biologging technologies beyond commonly applied lenses of surveillance and control.

In Chapter Six I considered a very different set of ways in which albatrosses are mobilised for conservation purposes, shifting attention from how they have been operationalised for surveillance to how they are used as vehicles of sentiment to cultivate care about environmental issues amongst different audiences. I proposed the concept of sentinels of sentiment to capture how animals are mobilised to communicate threats in their environments through appeals to affect, emotion and feeling, as opposed to or in addition to the scientific, reason-based logics commonly associated with sentinel species. In doing so, I also sought to build on the discussion in Chapter Four concerning how and why seabirds have become sentinels, approaching these questions from a different angle through the lens of sentiment. The "flight ways" of albatrosses – their particular ways of life and characteristics passed between generations (Van Dooren 2014) – were a common thread between these discussions, priming them for particular kinds of scientific research (Chapter Four), surveillance applications (Chapter Five), and sentiments (Chapter Six).

Three 'albatross stories' were outlined to articulate the concept of sentinels of sentiment. Across these stories, different sentiments, animal bodies, spaces of encounter,

and politics were at play. The 'Save the Albatross' round-the-world sailing voyage, in line with various 'Save the X' conservation campaigns, foregrounded the iconic, awe-some characteristics of the albatross, and appealed to a conservation aesthetic configured around wilderness and charismatic species under threat. This aesthetic is characteristic of a mainstream environmentalism of the Global North, and I showed how it was mobilised by corporate actors as well as elite figures like then-Prince Charles to support particular narratives beyond the remit of conserving albatrosses, including British 'belonging' in distant territories and marine spaces. The appeal of this aesthetic is far from universal, and I explored how conservationists have adapted their visual messaging for audiences for whom it is redolent of a legacy of culturally disrespectful conservation campaigning – in this instance, Japanese publics and policymakers critical of past anti-whaling campaigns by Western conservation NGOs. The cute and endearing characteristics of albatrosses – their "cuddly charisma" (J. Lorimer 2007, 919) – have been foregrounded in this context, and I argued this was also mobilised to navigate the logics and demands of digital cultures. A key argument I made here was that conservationists do not have a monopoly over sentiments, which I illustrated through photographer Chris Jordan's 'Midway' photographs of dead albatross chicks with stomachs filled with plastic waste. Conservationists and researchers expressed frustration that these images have unjustifiably skewed public perception of the threats facing albatrosses towards plastic pollution, and I used this as an entry point to discuss the tensions between an environmental politics grounded in scientific reason and one based around sentiment.

As I anticipated in Chapter Two, accounts of the digital mediation of human-nonhuman relations have tended to emphasise the role of digital technologies in hegemonic knowledge regimes, the entrenchment of capitalist relations, and the uneven exercise of power over humans and nonhumans. At different points in this thesis, I have sought to articulate an alternative, and more affirmative, situated mode of engagement which recognises these negative effects but retains an openness to others. In the last empirical chapter, this was developed through a focus the glitches and frictions, concepts repurposed from digital geographers and STS scholars, which complicate the smooth subsumption of oceanic and fisherly worlds according to computational logics. I explored the promise of a 'glitchy' reading of smart ocean governance transformations, shifting attention from

albatrosses back to seabirds more generally and to the on-board electronic monitoring (EM) technologies that, it is hoped, will make seabird bycatch more visible and amenable to effective governance. This is part of the broader promise of transparency invested in these technologies which, I argued, are mobilised according to a logic of "measurementality" (Turnhout, Neves, and De Lijster 2014). Hereby, effective governance is yoked to the collection of ever-expanding types and volumes of data.

The major conceptual development made in this chapter was to highlight the production of what I termed **selective transparency.** I put this forward to account for the ways in which transparency in environmental governance contexts can be performed when it is discursively indexed to the *deployment* of monitoring technologies and the *collection* of data, even as it is strategically undermined in practice through technological sabotage, cost-saving, and strategic decisions about the sharing and analysis of data. I suggested that this selective transparency involved marginalising seabirds as a matter of concern upstream, during, and downstream from the deployment of EM technologies on fishing vessels. The politics of selective transparency, which I positioned as favouring fishing industry interests, suggested a more tempered reading of the progressive potentialities of glitches and frictions than those which have been offered in the very early engagements with these concepts by environmental geographers (see Searle et al. 2023).

This chapter was not centrally about seabirds as sentinels. In this sense, it may have seemed out of place as the final port of call for the empirical analysis offered in this thesis. However, the chapter developed my overarching narrative and argument by attending to this context where seabirds are (purposefully) obscured from scientific and managerial vision. By diverging from the empirical focus of the other chapters, this chapter demonstrated the claim made in Chapter Two that the sentinel is not a property of an animal but something which is enacted through **practices** distributed across more-than-human **collectives** configured around anticipation and response to environmental threats. Animals can thus fail to materialise as sentinels in the absence of the practices and collectives necessary for them to do so. Moreover, reading across the four empirical chapters, we see how different practices and collectives materialise animals as sentinels in very different ways (as scientific samplers and platforms, surveillance technologies, and vehicles for sentiment), supporting

differing forms of environmental governance. This affirms the need for empirical attention to how and why particular animals become sentinels (and where they don't), rather than accepting ahistorical and decontextualised scientific claims that they simply *are*.

8.3. Key Contributions

This thesis thus makes a series of contributions to geographical literatures, which are noted at various points in the preceding chapters. I will reiterate and expand on them here, with an eye to the directions for future research that are discussed in the following section. The key contribution made herein has been to bring environmental sentinels more firmly into the sights of geographers, expanding on existing engagements by anthropologists and STS scholars. This has been informed by a specific sense of what geographical approaches have to offer studies of sentinels and what, in turn, sentinels might offer geographical scholarship. I have made this case by reading sentinels through approaches offered by more-than-human geographers, geographers of the ocean and ocean governance, and the emerging field of digital environmental geography, drawn together into the conceptual framework for sentinel geographies presented in Chapter Two and developed throughout the thesis.

Although more-than-human geographers have been my main conceptual companions in this work, environmental sentinels speak beyond their concerns to those interested more broadly in charting and critiquing shifts in the contemporary governance of human and nonhuman life (B. Anderson 2010b; B. Anderson and Gordon 2017; B. P. Braun 2014; Chandler 2018). Notably, the logics of vigilance and forewarning bound up with sentinel geographies resonate with recent scholarly interest in forms of anticipatory action through which, Ben Anderson (2010b, 777) suggests, "geographies are made and lived in the name of preempting, preparing for, or preventing threats to liberal-democratic life." However, as I have suggested in this thesis, the geographies and forms of governance associated with sentinels are not exactly analogous to those described by existing work on militaristic surveillance (see Gregory 2011; Nadim 2016) or enacting security regimes (Amoore and Raley 2017; B. Anderson 2010a; Petit 2020), nor even engagements with a 'cyborg anatamo-politics' whereby nonhumans become technologies for knowing and governing ecological turbulence (Barua 2021; see also Benson 2011; Gabrys 2016a). In particular, sentinels

introduce contingencies as well as more utilitarian or panoptical 'improvements' to sensing and governance practices. As different actors have attempted to introduce seabirds into their visions for knowing and governing ocean space, the practical and ethical limitations of such visions are thrown into relief. To know and govern together with nonhuman life necessarily involves more than filling epistemological gaps or developing modes of governance whereby more of an imagined totality is seen and rendered governable. It entails fraught negotiations across multiple human communities and on terms other than humans' own. Practically, the analysis presented in this thesis signals enormous challenges awaiting grander attempts to enact a planetary 'internet of *living* things' (Bakker 2024) or 'Gaia 2.0' (Lenton and Latour 2018) whereby nonhumans are connected into a "global network of animal sentinels of environmental change" (Jetz et al. 2022, 293).

This thesis has also contributed to how the ocean and ocean governance are approached in geographical scholarship. The triad of existing approaches I brought together concern the military and colonial histories and political economic relations shaping the production of ocean science (see Lehman 2019; Oreskes 2003), understandings of the Anthropocene ocean as a material, voluminous, and turbulent space (see Steinberg and Peters 2015), and engagements with novel approaches to 'smart ocean governance' (see Bakker 2022; Ritts and Simpson 2022). With notable exceptions, these different approaches have had an ambivalent relation to the agencies of animals in historical and contemporary ocean sensing and governance practices, privileging an understanding of the ocean as a "volume of flows" over a "web of life" (following Benson 2012). Understanding these practices as 'lively,' operating with and through animals' bodies and behaviours, this thesis has done much to foreground these agencies. Methodological innovation could open up opportunities to take this further still, which I discuss in the following section. An additional contribution here has been to further develop the application of 'milieu-specific' ways of thinking *with* the ocean (Jue 2020; see also Helmreich 2011; Steinberg and Peters 2015) towards thinking about the ocean as a governed space. This adds to recent interest in how the dynamic, volumetric, and material qualities of the ocean matter to how it, and the ecologies and lifeforms within the ocean, are governed (see Braverman and Johnson 2020). Two movements in this direction were made in Chapter Seven, where glitches and frictions offered new approaches through which to develop recent moves beyond celebration or

critique of digital transformations in ocean governance (Drakopulos et al. 2022); and in Chapter Five, where I suggested that a view of dynamic ocean management as a practical enactment of a 'wet ontology' (see Peters 2020) was usefully supplemented by an attention to environmental modes of biopower, in order to better grasp these new management approaches.

Critical engagements with questions of governance, particularly the large-scale digital transformations in ocean governance presently underway, are important and needed. However, recent work has also been interested in developing normative proposals collaboratively with practitioners for how governance might be 'done' in more just and equitable ways, for both human and nonhuman actors (see Millner et al. 2023; R. Pritchard et al. 2022; Sandbrook et al. 2021). Two such proposals have emerged in this work which might, through future collaborations, be transformed into contributions to practice. Recent work has noted that the pace at which digital solutions are being developed for environmental problems is greater than that at which rigorous frameworks are developed to govern them (see Turnbull et al. 2022). This 'outpacing' is more widely observed of digital transformations (Aspray and Doty 2023; Bennett Moses 2011). The enrolment of animals in conservation surveillance is one such domain in which clear frameworks have yet to be developed. The '3Rs' of animal research (replacement, reduction, and refinement; see NC3Rs 2023) offer an important starting point. However, the diversity of such approaches 'in the wild' suggests the need for a broader set of general principles, following the model of those developed for socially responsible use of conservation surveillance technologies (see Sandbrook et al. 2021). More context-specific deliberation is also needed concerning what specific risks are posed, what their likelihood and effects are, and how these are weighed up in relation to any proposed benefits to individual animals, species, or wider ecologies.

Secondly, the problem of 'selective transparency' outlined in Chapter Seven and the normalisation of surveillance discussed in Chapter Five suggest a need to look beyond top-down measures to press digital surveillance upon natural resource users towards the wider political economic forces driving malpractice (including problems like seabird bycatch) in extractive industries like fishing and a need for more participatory approaches. This is not a novel suggestion (see for example Holm et al. 2020; Toonen and Bush 2018), but the

prevalence of a mindset of top-down intervention and enforcement among my interlocutors – albeit countered by enthusiasm for participatory approaches among some – suggests there is much to be done to develop more inclusive digital governance regimes. Recent proposals to transition from 'smart city' to 'digital urban commons' approaches by democratising access to data, upholding the privacy, agency, and participation of users, and ensuring digital solutions meet well-defined policy goals (see Creutzig 2021; O'Brien 2018) might provide a blueprint for transitions from 'smart ocean governance' to governing a 'digital ocean commons.' In this vein, this thesis has sought to build on recent work which approaches the possibilities afforded by digital technologies for environmental governance in a generative and critically affirmative way (e.g. Turnbull et al. 2022), including work specifically attentive to ocean governance (e.g. Bakker 2022; Drakopulos et al. 2022). In the context of the scale of overexploitation and criminality characteristic of some fisheries, the prospects for more participatory (digital) governance approaches may seem slim, but pessimism, blame, coercion, and a lack of alternative frameworks beyond enhancing surveillance and control are likely to drive continued ecological destruction as much as to address it.

Finally, then, sentinel geographies as I have articulated it here offers a compelling new way in which to critique certain contemporary environmental sensing and governance practices which rely in various ways on organismal experiencing and signalling, but also to approach them in more affirmative and generative registers. Indeed, this thesis has sought to demonstrate through a particular set of examples how sentinels (understood at their broadest as more-than-human warning systems for multiple interconnected environmental crises with specific geographies) are an emergent and significant component of environmental sensing and governance practices. Sentinel geographies is proposed as a field of inquiry through which scholars might understand their operation while remaining open to both their negative and more progressive potentials, and connect and compare sentinels with other ways in which contemporary environmental conditions and threatening futures are rendered knowable and actionable. As I discuss further in the following section, researchers might also develop their own ways of working *with* sentinels to bring the ecological and organismal effects of multiple interacting environmental crises into focus, inviting different appreciations of ecological systems and developing proposals for alternative modes of living with and governing them. For instance, by drawing attention to organisms

which are affected by, and signal the effects of, the interactions between multiple stressors – for instance, oceanic plastic pollution, fisheries overexploitation, climate change, and so on – there is promise in proactively mobilising sentinels to signal insufficiencies in fragmented and siloed approaches to governance which often consider these in isolation. Hereafter, alternative proposals which build out from the organism and its altered ecologies might be developed.

8.4. Reflections and future directions

There are several conceptual and empirical directions which I identified in this research which remained little or unexplored. My first observation is that there is still significantly more to be said about seabirds – as sentinels and otherwise. As I noted in Chapters One and Four, there is growing interest in birds amongst more-than-human scholars, centred around the new kinds of affective attunements, atmospheric engagements, and research practices birds afford (see Petri and Guida 2023). This builds on existing work in environmental history and the history of science which I have suggested is weighted notably towards the human in human-bird relations. These literatures have so far taken little interest in seabirds. I have made a first pass at bridging between these literatures and concerns amongst scholars of the 'blue turn,' and suggest seabirds might further act as a 'boundary object' for future work: as beings which connect, through their bodies and mobilities, oceanic, atmospheric, and terrestrial worlds and thereby bring together these areas of inquiry. In particular, recent scholarship on the ways that the ocean 'exceeds' its material volumes, extending beyond itself into terrestrial and atmospheric spaces, ecologies, and imaginations (Bear 2013; Peters and Steinberg 2019), is likely to benefit from engaging with seabirds. In a slightly different vein, seabirds' geographies – as an extension of recent terrestrial-centred engagements with animals' geographies (see Hodgetts and Lorimer 2015) – might provide a focus for future methodological innovations, building upon my efforts to account for these birds' affordances here. This thesis, then, is intended as an opening into the rich empirical and conceptual affordances of seabirds, not a closure.

Equally, more might have been said in this research about the ways in which wildlife tracking and biologging technologies, and the data they generate, are being repurposed to

serve environmental governance purposes. Whilst I chose to focus on the Ocean Sentinel project in Chapter Five, there were other promising and different examples which emerged through interviews and document analysis which I did not explore. For instance, in 2021 the 600,000km^2 North Atlantic Current and Evlanov Sea-basin marine protected area (MPA) was designated based on seabird tracking data collated by BirdLife International, which indicated the importance of this area to seabirds across the North Atlantic. As the first MPA to be designated based on animal tracking data, this raises interesting new questions around the agencies of animals in marine spatial planning, as does the emergence of the dynamic ocean management approaches discussed in Chapter Five. Emerging approaches to enacting landscape connectivity more dynamically in terrestrial conservation suggest such questions will not be limited only to marine contexts (see Unnithan Kumar et al. 2022). There was not scope to extend this line of inquiry further here, but there is much to be explored for geographers interested in the spatial practices of biodiversity conservation and, as I suggested above, a range of new considerations for conservation practitioners to address.

Fishing, fishers, and fisheries management have come in and out of focus in this thesis, featuring particularly in Chapters Five and Seven. There is significant scope and value to expanding ethnographic studies of fishers' engagements with the transformations in marine governance which are shaping their lives and livelihoods. Recent investigations of how agricultural sector actors engage with climate metrics shaping their practices point to one way forward (see Cusworth et al. 2023). To engage these more fully would have taken this thesis in a different direction, and I chose not to because of a combination of the logistical challenges of doing so and their somewhat tangential relations to my main concern with seabird sentinels. There were, however, clearly other stories that might have been told here, and recent ethnographic engagements with fishing and aquaculture highlight promising directions (Lien 2015; Telesca 2020). Where I have been critical of commercial fishing practices and fisheries management, it is crucial that this is not conflated with a condemnation of fishers themselves, who, as anthropologist César Giraldo Herrera (2022, 1154) notes, "often obliged by circumstances, carry the burden of exerting violence towards nonhumans." Doing so contributes to the precariousness of those employed in the fishing industry, downplays the significance of fishers' ecological knowledge and skill, and seeds resentments amongst fishers which often find expression in poorer animal welfare or

outcomes for fisheries management (Giraldo Herrera 2022). Fishers' knowledges and perspectives, often sidelined by modernist fisheries management, are vital to the good governance of fisheries (Holm et al. 2020; Pálsson 1998), and may inform new geographical work that engages more constructively with pressing ocean governance questions (see Cardwell and Thornton 2015).

Finally, sentinel geographies might be taken forward in new directions. There are many possibilities here, and thus in a non-prescriptive spirit I suggest two promising directions. The first is to engage the kinds of emerging multispecies sentinel systems noted above and in the Introduction – one of which, the International Cooperation for Animal Research Using Space (ICARUS), even proposes a global network of 100,000 digitally tagged sentinel animals across 500 different species for biological Earth Observation (Jetz et al. 2022). The concern in following such emerging systems is that they are presently more speculative than grounded in practice (they may, in other words, remain the wild dreams of scientists). This is in itself interesting, however, and tracing the practices of the different actors involved in trying to enact these systems would likely offer fascinating insights into technoscientific hubris if not the realisation of a large-scale reordering of nonhuman life according to the logics of Earth Observation.

Secondly, sentinel geographies might engage with a more diverse set of epistemic communities than I have here and further explore the politics of expertise surrounding environmental sentinels. In Chapter Six I noted that the capacity to mobilise animals as sentinels is not the reserve of any one epistemic community – such as ecological scientists – and future work might expand on this claim. Given that sentinels are associated with assertions about what environmental problems *are* and how they might be addressed, who is in the position to make such claims and how might they be contested by others with different understandings or even operating from alternative ontologies (see Gramaglia and Mélard 2019 for one example)? Are alternative sentinels proposed 'upwards' to challenge technoscientific claims and to configure environmental problems differently, and if so, what kinds of political struggles result? My sense, which I perpetuate here, is that existing social scientific engagements with sentinels have largely been guided towards important sentinels via the taxonomies produced by scientists more so than others. On one level, this clearly

makes sense; the sentinel species is, after all, an ecological concept. However, what alternative sentinel geographies might be possible with broadened horizons? One avenue I find especially promising is to turn to what anthropologists Anna Tsing and colleagues (2019, 186) term “feral proliferations”: to those nonhuman ways of life which are flourishing and creating “feral effects” in the simplified ecologies of the Anthropocene. Tsing and colleagues offer the example of the coffee rust fungus, which weakens coffee plants and has spread globally across coffee plantations with disastrous effects for production. There are countless others like the coffee rust fungus which are, undoubtedly, environmental sentinels even if they have not yet been described by scientists in those terms. It is their proliferation, not their decline, that is experienced as a warning of ecological dysbiosis and an incitement to action. There are opportunities here for new sentinel geographies whose starting point is to narrate environmental change from the perspectives of new and troublesome ecological relations that are coming into being, as well as from those which are falling apart.

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