AniBOS

Proposal to form the GOOS network,
Animal Borne Ocean Sensors

April 24, 2020

Looking at our changing oceans through the eyes of marine animals

Our Vision

To enhance understanding and describe our changing oceans
through the eyes of marine animals

Our Mission

Collect and make freely available oceanographic measurements from the most inaccessible regions of the global seas to understand our Changing Oceans.

Summary

The primary goal of the network Animal Borne Ocean Sensors (AniBOS) is to provide a cost-effective and complementary capability to the Global Ocean Observing System (GOOS) to monitor essential ocean variables (EOV) and essential biodiversity variables (EBV), by providing inputs to estimates of global ocean indicators, and contributing to a global quantification of the seasonal and interannual variability of the upper ocean state.

Here we describe our proposal for a global network of animal-borne ocean sensors. AniBOS will greatly enhance observations of temperature and salinity (TS) in the upper ocean which are urgently needed to sustain improved understanding of climate variability and ocean variability. The animal-borne observations also contribute unique TS observations that can be integrated with other observations, such as those from Argo, Ships, and gliders, to inform a range of operational oceanographic applications.

Each animal borne sensor is expected to gather on average 500 temperature-salinity-depth profiles annually in the high latitudes, coastal shelves and tropics, all regions that are currently poorly covered by traditional observing platforms. The observations in these remote areas of the ocean will fill large observational gaps that presently exist in the global observing network. They will also provide crucial information for ocean state estimation, and when integrated with other elements of the climate observing system, will greatly enhance studies of climate variability and deliver data to inform climate prediction estimates at global and regional scales.

Importantly, these hydrographic observations also provide a wealth of data on animal movements and behaviour that directly link environmental state and animal performance. This knowledge is essential to plan and develop evidence-based policy that is beneficial to protecting the animals and their habitats from increasing human activities through an understanding of their biology and spatial ecology.

A growing number of ecological studies and management applications are made possible by the use of bio-logging and animal-borne instruments. However, there is still a gap in the integration of such sensors with global ocean observing systems. Formal recognition of the animal borne ocean sensors network within OCG GOOS will improve our ability to observe and understand the oceans, the animals that live in them, thus contributing to improved understanding of global climate processes for societal benefit. Consequently, recognition under the OCG GOOS framework is an important vehicle for designing, building and broadening, through enhanced visibility, cross-network collaboration and communication, the use of animal derived ocean observations.

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Background

The United Nations has released (2019) its **Decade of Ocean Science for Sustainable Development (2021-2030)** vision where its primary goal is to "support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide behind a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the Ocean" (Ryabinin et al. 2019). In addition to this contribution to the Decade of Ocean Science, AniBOS will fill critical information gaps in support of the United Nations Sustainable Development Goal 14 that aims to: "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" (https://undocs.org/E/2019/68). Essential to achieving this goal is obtaining information on the state of the global ocean in space and time through a "deep disciplinary understanding of ocean processes and solution-oriented research to generate the knowledge needed for reducing pressures on the ocean, preserving and restoring ocean ecosystems and safeguarding ocean-related prosperity for future generations". While much of the physical environment of the globe's oceans have been sampled to some extent, some important areas remain difficult to sample: the high polar latitudes, across coastal shelves, the world's tropical oceans, and the deep ocean. Moreover, data on the globe's ocean biogeochemistry and Essential Biodiversity Variables are also lacking. The primary reason for these observational gaps is the difficulty for conventional observing platforms such as ships, expendable bathythermographs (XBTs), and Argo floats to penetrate into these regions and collect sustained longitudinal observations. Animal-borne oceanographic sensors present a solution to fill these gaps and are increasingly seen as an essential component of an integrated global observing system (Harcourt et al 2019, March et al 2019, Miloslavich et al 2019, Newman et al 2019, Treasure et al. 2017, Hussey et al 2015, Roquet et al. 2014, Roquet et al. 2013).

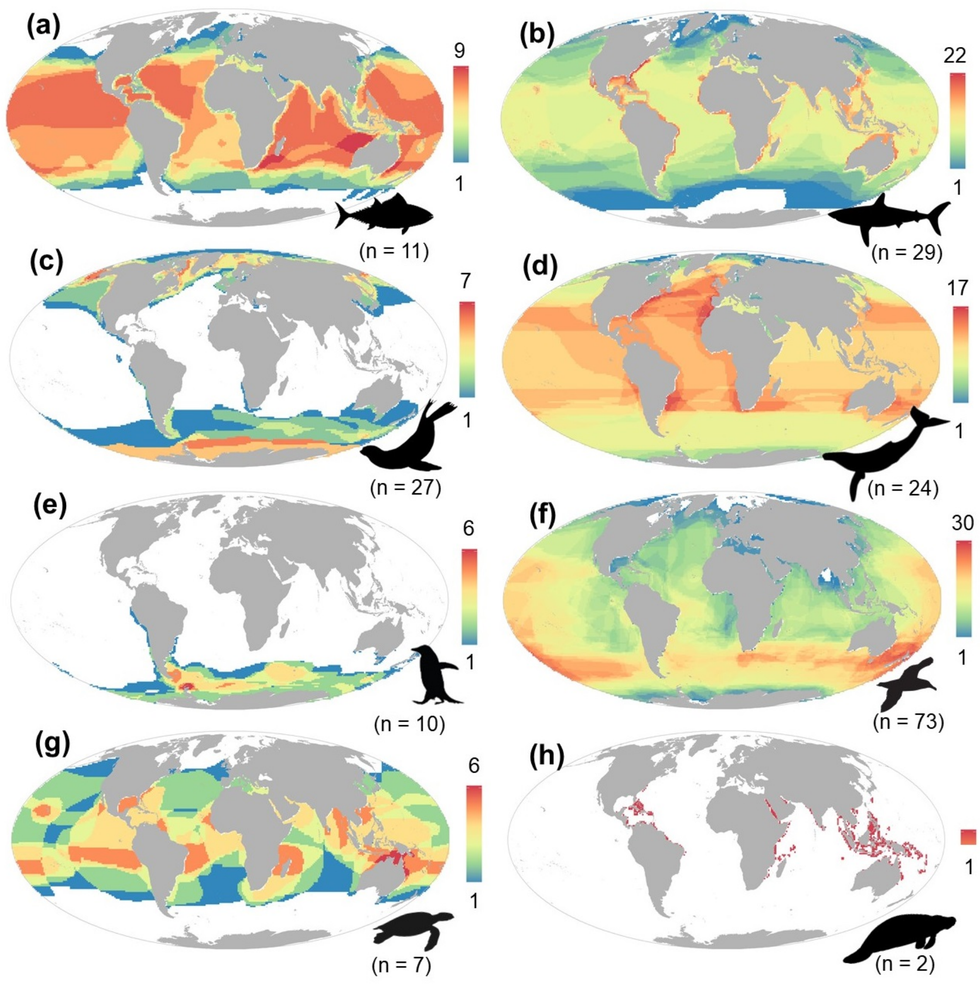
Central to understanding earth's climate is a thorough understanding of ocean physics and how it is changing especially in the high latitude oceans in the Antarctic and Arctic. This is because of the key role that vertically migrating marine animals play in global heat and carbon cycles; more than 90% of the Earth's Energy Imbalance (EEI) is stored in the oceans (Abraham et al. 2013). Of particular importance for understanding the EEI is the upper part of the Antarctic Circumpolar Current that has warmed at twice the rate of the global upper ocean. The Southern Ocean is considered to be the dominant region of heat and CO_2 exchange (Frölicher et al. 2015). To date, the global research community has relied largely on i*n situ* measurements of ocean temperature from Argo floats to quantify this imbalance (Roemmich et al. 2015, Riser et al. 2016). These measurements, however, have some limitations, particularly in the ice-covered high latitudes where observations from ice-penetrating Argo are still sparse (Roemmich et al. 2009, Smith et al. 2019). The advent of miniaturized temperature and conductivity sensors that can be attached to marine animals has revolutionized ocean observing (Fedak 2004) by providing an avenue to observe some of the most remote ocean realms on Earth under some of the harshest conditions on the planet *e.g.* under Antarctic sea-ice during the winter (Roquet et al. 2014, Treasure et al. 2017). Observations from animal-borne conductivity-temperature-depth (CTD) instruments, in particular those attached to southern elephant seals, are filling this gap (Roquet et al. 2013). Increasingly these observations are central to understanding physical processes such as ice formation dynamics (Charrassin et al. 2008, Tamura et al. 2016, Guo et al. 2019), Antarctic Dense water formation (Ohshima et al. 2013, Kitade et al. 2014, Williams et al. 2016, Mallet et al. 2018), ocean and ice shelf dynamics and interactions (Silvano et al. 2016, Silvano et al. 2018) and frontal system identification and dynamics (Pauthenet et al. 2018). Animal-borne sensors are also providing observations on animal behaviour, *in situ* environmental structure (e.g. Labrousse et al. 2017a, Labrousse et al. 2017b), and the consequences of differences in environmentally mediated behaviour at the population level (Hindell et al. 2016, Hindell et al. 2017, McMahon et al. 2017).

Animal-borne oceanographic sensors have a central contribution to make in monitoring ocean climate signals. Measurement of temperature and salinity are needed to understand the large-scale variability in the thermohaline characteristics of the ocean. The animal-borne sensors complement existing observational sampling systems, such as Argo profiling floats and ship-borne deep ocean hydrographic sections, by targeting areas not currently well covered by these technologies including sea ice covered seas and continental shelves shallower that 1000 m (the drift depth of Argo floats), for example, around Antarctica or around small islands on major plateaus, e.g., the Kerguelen or Campbell Plateaus.

The use of animal-borne sensors provides unique capability, as knowledge of the animal's behaviour and ecology can be used to provide predictable repeatability of observations and to target specific geographic areas and/or oceanographic features. These include: the high latitude polar regions, coastal shelves and near shore waters. The ability to target specific regions is significant, as no other technology provides the capability to sample these spatio-temporally dynamic features in this way. The ability to target specific features like fronts is particularly important in the Southern Ocean where subduction along fronts is an important mechanism for drawing heat into the deep ocean. Animal-borne sensors have already been instrumental in understanding heat transport on the Antarctic continental shelf, the inflow of Warm Deep Water onto the continental shelf and underneath the ice shelves and the production of cold, dense and oxygenated Antarctic Bottom Water (Williams et al 2016). Monitoring heat transport on the Antarctic continental shelf is required to understand processes involved and to predict the ice shelf melt. The formation and export of cold, dense and oxygenated Antarctic Bottom Water is one of the key processes that drives the global thermohaline circulation. Changes in these processes lead to the break off and melting of ice shelves, leading to sea-level rise and alterations to the global thermohaline circulation. Monitoring these processes is required to understand and predict tipping points in global climate change. Animal borne sensors are able to measure water mass properties year-round, especially in winter when these areas are otherwise inaccessible.

Animal "sampling platforms" are not only excellent physical oceanographic samplers but, they can also carry instruments that collect essential biogeochemistry (chlorophyll *a* and dissolved oxygen) and ecological information (Bailleul et al. 2015, Sauzede et al. 2015, Vacquie-Garcia et al. 2017, Harcourt et al. 2019). This uniquely places animal-borne sensor observations in a position to address scientific questions which are at the interface between physics and biology and aligns elegantly with other biological ocean observing network initiatives including Biogeochemical Argo (Claustre et al. 2019). This provides the basis for quantifying, at a fundamental level, how physical oceanographic processes control the distribution and abundance of preyfields and influence the foraging success of top predators. As predators integrate information across multiple trophic levels they are used as sentinels of the ecological consequences driven by global climate change, which can be difficult to address with physics only observing systems. This is a significant advantage that is unique to the network in that it also provides EBVs relevant to GOOS.

Animal tracking data are increasingly being used for the conservation and management of marine systems. On their own, tracking data can elucidate spatial stock structure and trans-boundary movements for fisheries assessment in support of emerging ecosystem-based management. When combined with oceanographic information, movement data can be used to identify ecologically important areas and help guide the development of spatial management approaches such as Marine Protected Areas. Data collected by this network will be of particular value as it will directly link ocean profiles with animal behaviour because both are recorded on (and transmitted from) the animals simultaneously, removing the problems of temporal and scale mis-matches that occur in other studies.

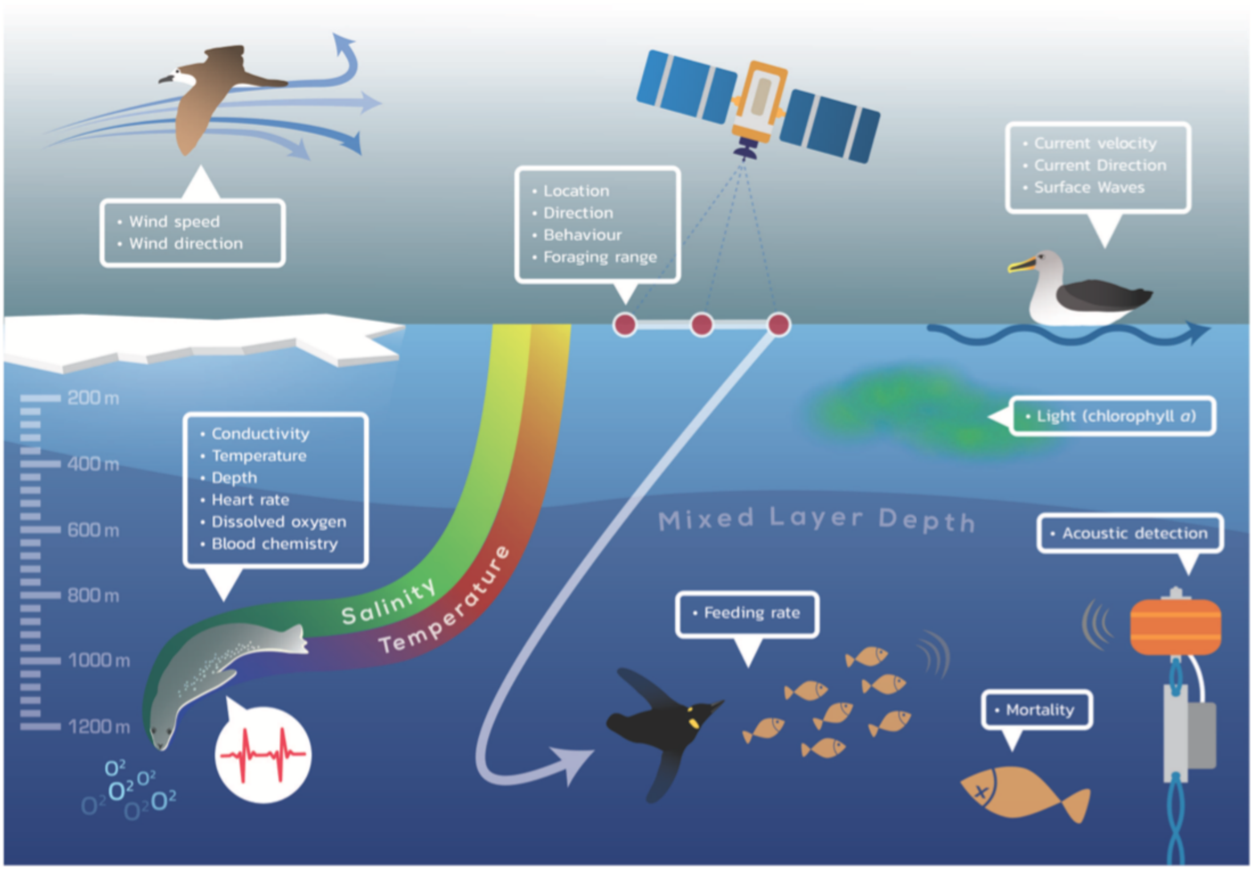


Density maps of species subject to telemetry by taxonomic group. (a) Tuna and billfishes, (b) sharks and rays, (c) pinnipeds, (d) cetaceans, (e) penguins, (f) flying seabirds, (g) turtles and (h) sirenians. (March et al, 2019).

Scope of AniBOS Network

The AniBOS network is unique because it delivers across three essential GOOS objectives of global importance: ocean health, climate, ecosystems and operational services. The network has three primary objectives.

1. Collect and disseminate high quality and high frequency observations of physical and biogeochemical oceanographic data in a standardised manner that is consistent across sampling platforms.
2. Provide *in situ* habitat data at the scale and resolution at which animals operate in the ocean to understand how they respond to ocean variability and change.
3. Provide a foundation for understanding how animals respond to a dynamic, changing ocean, in particular by integration with existing and new and emerging GOOS networks.



Schematic illustrating the many parameters that can be measured by animal-borne ocean packages, using archival, acoustic, or satellite telemetry. The environmental, physiological, and ecological data collected by the illustrative marine animals (penguin, seabird, fish, seal) may be measured in multiple ways and stored or transmitted or both. Adapted from Harcourt et al. 2019.

Membership, standards and best practice

There currently are a wide range of animals carrying ocean sensors in the world's oceans and these observations can fill important observational gaps in the global ocean observing system (Harcourt et al. 2019, March et al 2019). The network welcomes observations from across this broad spectrum of animals, regions and sensors but stresses that only those observing networks that comply with the following can be considered for membership:

1. Sensor type and quality needs to comply with the minimum requirements for accuracy and precision determined by the AniBOS Scientific Steering Committee
2. Follow the ethics and best practice of the network outlined by the ethics subcommittee
3. In accordance with most up-to-date recommendations in the literature

The network will be committed to a strong framework for consistent data delivery, standardised measurement techniques, deployment and sampling, reference materials and standards, calibration and validation, data retrieval and formatting, primary and secondary quality control. Currently there are a number of well-established and ongoing, *i.e.* improvements, and additions that are constantly being implemented, set and peer reviewed protocols that act as a guide for the community to ensure best practise and these are summarised in the following Table.

Description	**References**
Animal welfare	(Wilson and McMahon 2006, McMahon et al. 2008, McMahon et al. 2012, Horning et al. 2019)
Animal capture	(McMahon et al. 2000, Field et al. 2002, Horning et al. 2019)
Instrument attachment	(Field et al. 2012)
Experimental design	(Sequeira et al. 2019b)
Instruments	(McMahon et al. 2005, Boehme et al. 2009)
Data quality control	(Roquet et al. 2011, Hoenner et al. 2012, Guinet et al. 2013, Jonsen et al. 2013, Roquet et al. 2014, Biermann et al. 2015, Lowther et al. 2015, Jonsen 2016, Jonsen et al. 2018, Mensah et al. 2018, Siegelman et al. 2019)
Governance	(Apostle et al. 2016, Jabour et al. 2016, Jeffers and Godley 2016)
Conservation	(Hays et al. 2016, Jeffers and Godley 2016, McGowan et al. 2016, Hays et al. 2019, Hindell et al. 2020)

Current and future needs

Developments in Telemetry Technology

In the decade since OceanObs 09, the application of animal telemetry has provided significant amounts of oceanographic data from otherwise difficult to sample situations. Furthermore, ocean observing using animal-borne platforms has demonstrated the importance of animal telemetry data for a broader understanding of ocean processes (Roquet et al., 2013). Nonetheless, improvements in accuracy and reliability as well as expanding the range of sensors on animal tags is clearly important, as is broadening the applicability to more and varied species. These developments include new, small, low-power sensors that sample additional parameters at extremely low duty cycles to allow for continuous monitoring of animals. For example, sensors for fluorescence (Guinet et al., 2013), oxygen (Bailleul et al., 2015), light levels (Teo et al., 2004), sound (Cazau et al., 2017), acceleration (Carroll et al., 2014, 2016; Cox et al., 2018), and active sonar (Lawson et al., 2015) have all been deployed , but most require further refinement. Each of these will contribute to a better understanding of the link between physical, biogeochemical, and ecological processes.

Where are we now?

The functionality of Argo floats is limited in polar regions due to the seasonal presence of sea ice that prevents floats from returning to the surface. Instrumenting free-ranging, air- breathing animals that move through sea-ice covered areas, such as seals, with temperature and salinity sensors can help fill data gaps in the Argo dataset in sea ice regions (Fedak, 2013; Treasure et al., 2017). To date, over 540,000 profiles have been collected in polar regions by marine mammals and made available to the broader operational and research oceanography communities (Roquet et al., 2014) (http://www.meop.net/).

The great potential provided by animal-borne sensors for monitoring oceanographic conditions and how animals respond to them was demonstrated following the deployments of CTD-SRDLs on southern elephant seals in 2004– 2005 (Biuw et al., 2007; Charrassin et al., 2008). These early data helped refine our knowledge of the Antarctic Circumpolar Current (ACC) frontal structure and hydrography in the South Atlantic (Boehme et al., 2008; Meredith et al., 2011) and in the vicinity of the Kerguelen Plateau (Park et al., 2008; Roquet et al., 2009), with applications for tracking ACC fronts (Pauthenet et al., 2018) or for estimating rates of sea ice formation (Charrassin et al., 2008; Williams et al., 2011). In 2011, observations from animal-borne CTD-SRDLs were central to solving a 30+ year-old puzzle regarding Antarctic Bottom Water formation in the Weddell-Enderby Basin (Ohshima et al., 2013). Observations of very high salinity shelf water were linked to a new source of Antarctic Bottom Water in the intense Cape Darnley polynya. Furthermore, Williams et al. (2016) demonstrated that Prydz Bay, situated just east of Cape Darnley, makes a secondary contribution to Antarctic Bottom Water due to the production of dense shelf water near the Amery Ice Shelf (also see Xu et al., 2017). A minor source of Antarctic Bottom Water was also detected at Vincennes Bay (Kitade et al., 2014), supporting the idea that several East Antarctica polynyas contribute to Antarctic Bottom Water formation. However, the ongoing freshening by glacial melting may compromise the ability of polynyas to form this Bottom Water in the future (Williams et al., 2016; Silvano et al., 2018).

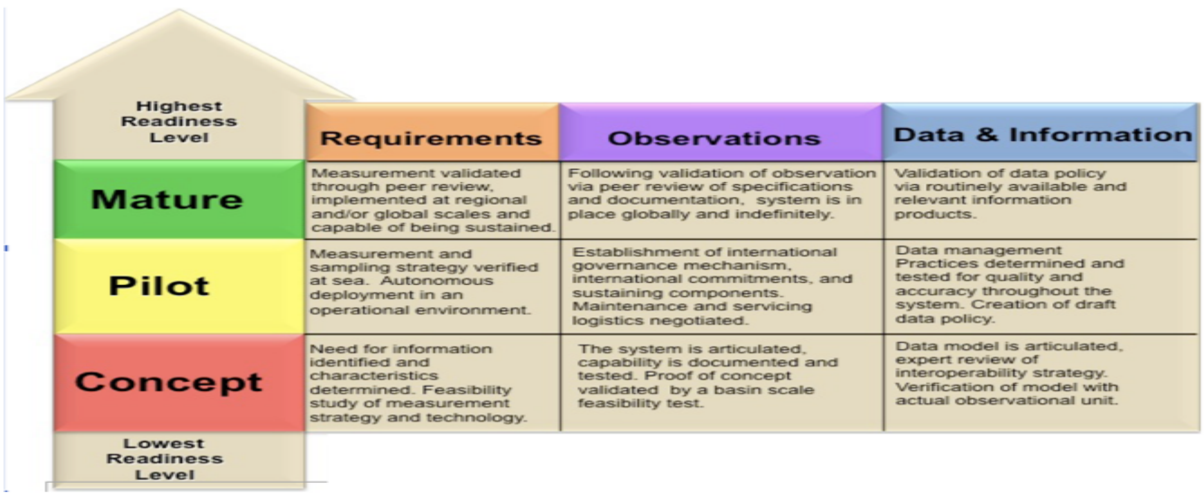
Animal-collected data have also been very successful in documenting local circulation and seasonal variability of water properties over the Antarctic continental shelf. Costa et al. (2008) analyzed the upper ocean heat content variability in the west Antarctic Peninsula using instrumented seals, providing a valuable reference to evaluate numerical circulation models. Using the maximum depth of benthic dives, Padman et al. (2010) identified troughs in the continental shelf that allow intrusions of Circumpolar Deep Water under the Wilkins Ice Shelf, accelerating its collapse (Padman et al., 2012). Animal- collected data also helped to characterize the exchange of properties across the shelf break in the Weddell Sea, linked to eddy overturning (Nost et al., 2011) and wind forcing variability (Arthun et al., 2012). Zhang et al. (2016) described intrusions of modified Circumpolar Deep Water into the continental shelf waters of the Bellingshausen Sea, with important implications for the stability of the West Antarctic Ice Sheet. Mallett et al. (2018) presented new insights on the distribution and seasonality of Circumpolar Deep-Water properties in the Amundsen Sea. More broadly, the animal collected data is biased seasonally and spatially, but by merging animal-collected data with ship-based and Argo float observations, Pellichero et al. (2017) provided the most comprehensive assessment of the seasonal cycle of Southern Ocean mixed-layer characteristics to date.

Animal CTD-SRDLs have become a valuable data source in several sectors of the North Atlantic Ocean. Straneo et al.(2010) used hooded seal (*Cystophora cristata*) data from the East Greenland Shelf to estimate seasonal temperature variations of subtropical waters sitting near the entrance of a major glacial fjord. Variability of these continental shelf waters was further investigated by Sutherland et al. (2013). Instrumented ringed seals (*Pusa hispida*) have also proved useful to investigate freshwater runoff from the Greenland Ice Sheet (Mernild et al., 2015) and freshwater discharge plumes from glaciers in Greenland (Everett et al., 2018) by providing observations from directly adjacent to the glacier tongue. Grist et al. (2011) used Argo and marine mammal profiles to produce a gridded data set that revealed distinctive boundary current-related temperature minima in the Labrador Sea and at the East Greenland coast (Isachsen et al., 2014). Isachsen et al. (2014) used data collected by instrumented hooded seals as well as Argo floats to reveal warmer and saltier conditions over much of the Nordic Seas in 2007–2008 compared to the 1956–2006 climatology. Exchanges of warm Atlantic Water across the shelf west of Spitsbergen were found to be primarily controlled by surface heat flux through the generation of an eddy overturning (Tverberg et al., 2014).

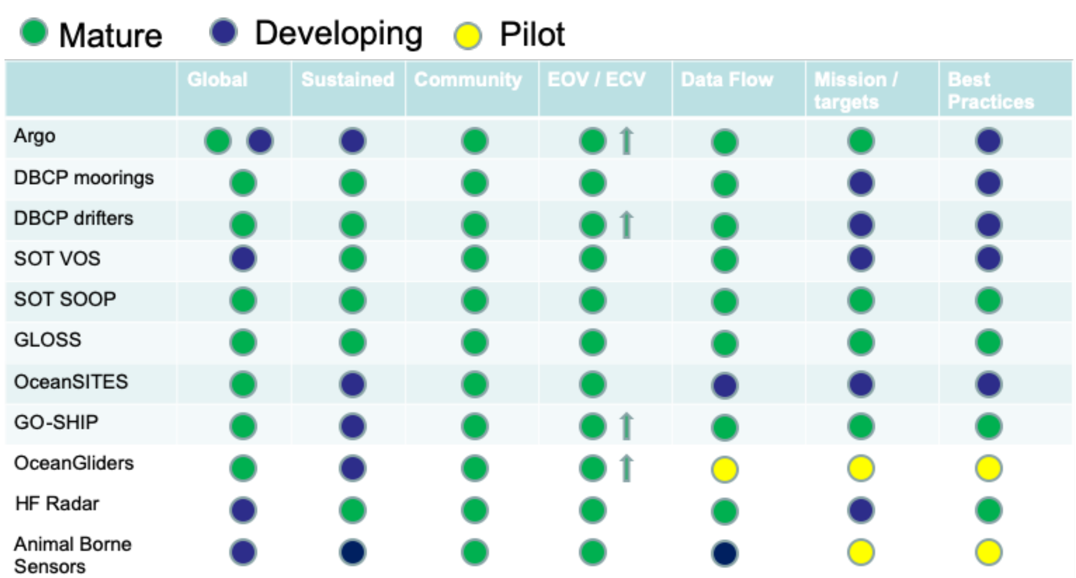
Animal CTDs have the potential to make similarly important contributions to temperate and tropical coastal systems. Turtles, sea lions and sharks are all species that can be easily tagged and which spend large amounts of time in shelf waters (Sequeira et al. 2018). These regions were highlighted as being of particular interest at OceanObs 19.

Transitioning to an Observing Network

Typically there are seven main attributes for an observing network recognised by the OCG. To be considered as a network there needs to be a demonstrated willingness to transition through the three phases of development *i.e.* Concept to Pilot to Mature, under the general framework of *The concept of Readiness (A Framework for Ocean Observing. By the Task Team for an Integrated Framework for Sustained Ocean Observing (IFSOO). UNESCO 2012 (IOC/INF-1284). DOI: 10.5270/FOO)*. While the latter was specifically proposed to apply to Essential Ocean Variables, the general concept is useful in terms of assessing the networks readiness levels. Below we rank the attributes of the network using the Concept of Readiness as a guide.



The GOOS-OCG publishes every year an assessment of the level of maturity and readiness for each GOOS-OCG network (see Table below). The network AniBOS, previously named "Animal-Borne Sensors" within OCG, has been evaluated in this way.



Summary of the maturity levels of the GOOS-OCG networks (nov 2019, source: E. Heslop)

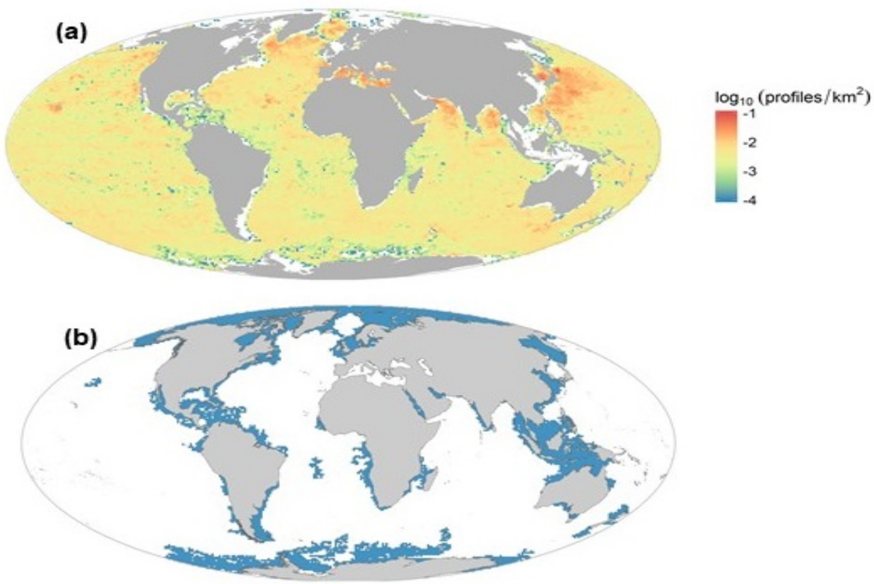
The seven attributes and where AniBOS is placed on the Readiness Scale, are as follows:

1. ***Global in scale***: Currently the network is concentrated in high polar regions where it is regionally **mature and sustained,** but given the broader potential for the network to expand to observing tropics/coasts the network is still in the **concept/pilot** phase.
2. ***Sustained observations***: In the Southern Indian Ocean we have a proud record of nearly 15 years of sustained observations illustrating our ability to sustain observations. We might therefore be considered **mature** in this regard.
3. ***Community of Practice***: Here our network is still developing and we would consider it to still be in the **concept/pilot** phase.
4. ***Observes at least one EOV or ECV***: The network, especially the polar programs, have contributed more than 500 000 T-S casts from the polar oceans, and Marine Mammals Exploring the Oceans Pole to Pole (MEOP) is now also including T-S casts from the tropics. We consider the network to be **mature**, but this will be enhanced further through formal recognition.
5. ***Delivers data free, open, and available in a timely manner***: Currently data from the polar programs are made available, through MEOP, to the broader scientific and research community (usually with an 18-month delay) and real-time (typically within 24 hours) observations to the operational community through the GTS (Global Telecommunications System). The network is currently **pilot** but can transition swiftly to **mature**.
6. ***Maintains network mission and targets***: We aim to work closely with JCOMMOPS to consolidate data management systems to deliver datasets consistent with other networks. The network is **pilot** but can transition to **mature** swiftly
7. **Develops, updates and follows Standards and Best Practice:** The community has a strong framework for consistent data delivery, standardised measurement techniques, deployment and sampling, reference materials and standards, calibration and validation, data retrieval and formatting, primary and secondary quality control, file and metadata standards compliance consistent with ARGO specifications. The network is mature but integration with JCOMMOPS will cement the network's status. A focus for the network is to improve search and delivery mechanisms for the MEOP data to the broader oceanographic community.

The network AniBOS can be built upon a stable foundation following 15 years of collaboration amongst national teams with the consortium MEOP. It is in a state of readiness that can be best compared with the network OceanGliders. Particular consolidating efforts will be required to build a sustained network with a stable data flow and well documented standards and best practices.

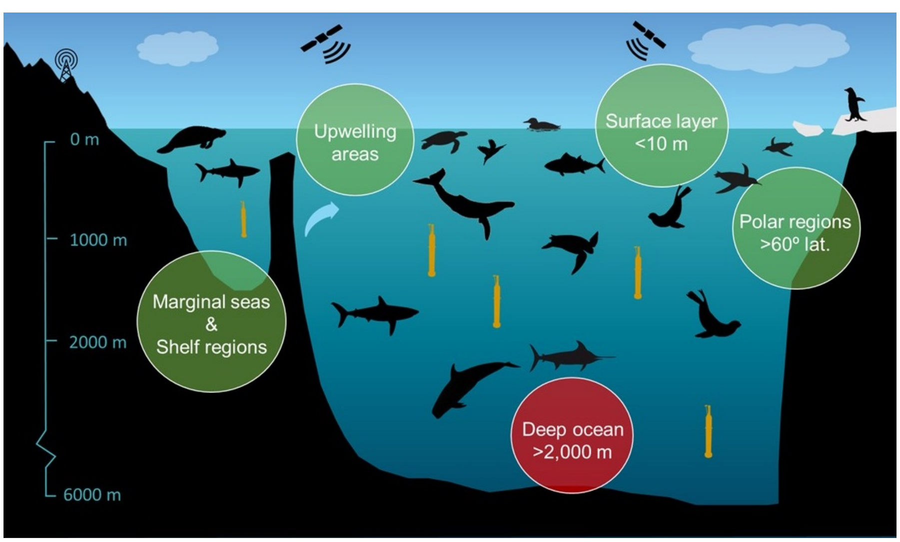
Mapping past, present and future coverage

A recent review (March et al. 2019) assessed the gaps in oceanographic monitoring at a global scale, focusing on the Argo network due to its global coverage and operational capacity to provide vertical profiles. This provides evidence that important regions are still under-sampled and highlights the political challenges of sampling within EEZs. In addition to high latitudes, other larger areas at mid-latitudes and tropical regions would require additional monitoring efforts.



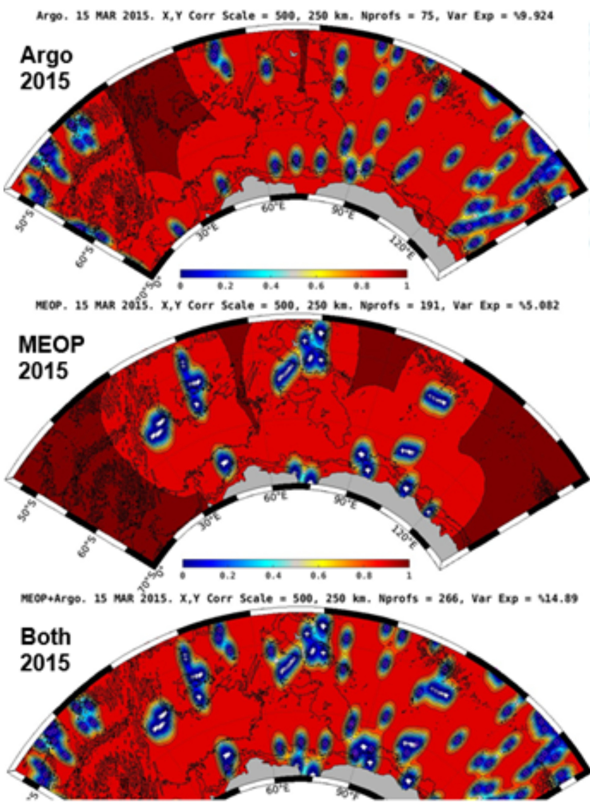
Global patterns of the spatial distribution of the Argo network for the period 2005-2016. (a) Density distribution of Argo profiles, (b) Argo coldspots (i.e. spatial coherent structures larger than 25 square degrees with a gap persistence rate of ≥80%). (March et al. 2019)

AniBOS has the potential to interact and contribute to current ocean observing initiatives worldwide both in the coastal (nearshore stations) and open ocean areas (moorings, gliders and animals) using past and current initiatives as described by Harcourt et al 2019, Hindell et al 2020, Newman et al 2019). The complementarity of animal-borne sensors with the rest of the observing system has been well documented particularly in the Southern Ocean (Roquet et al. 2013).



Animal-borne instruments can contribute in marginal seas, upwelling areas, the upper 10 m of the water column, shelf regions and polewards of 60° latitude (represented on the horizontal axis). Vertical distribution of taxonomic groups reflects the median and maximum dive depths. (March et al. 2019).

This can be demonstrated quantitatively through an analysis of relative data coverage. As an illustration, we quantify the synergy of MEOP with Argo in the Indian sector of the Southern Ocean (analysis done by M. Mazloff, Scripps, USA). Data from 2005 to 2015 collected between 13-17 March, 45^{o}S-90^{o}S, and 0^{o}-140^{o}E are used. An objective mapping (correlation lengths of 250km in the meridional direction and 500km in the zonal direction) was then carried out each year using only Argo data, only MEOP data, and the combined observing system. We analyzed the formal mapping error for these three observing systems. The variance explained in the region from Argo ranges from approximately 10% to 22% (see figure below). Meanwhile MEOP explains 1% to 7% for this period each year. Most importantly, the observing systems have little overlap and are extremely complementary. This can be seen by the raised variance explained in the combined Argo-MEOP observing system. The combined system explains 13% to 26% of the variance in the region. The average variance explained between 13-17 March in the region between 2005-2015 was 16% for Argo, 4% for MEOP, and increased to 19% for the combined observing system.



Variance unexplained: red, 1, implies no constraints; blue, 0, implies fully constrained

15 Mar of Year	N Argo	N MEOP	% VE Argo	% VE MEOP	VE Both
2005	77	75	10.5	2.7	13.2
2006	110	219	14.7	1.3	15.9
2007	98	142	13.6	1.9	15.6
2008	130	288	14.3	6.9	20.1
2009	162	230	17.6	3.9	20.9
2010	187	98	21.3	2.7	23.5
2011	179	444	22.2	4.2	25.7
2012	219	336	21.5	3.0	24.1
2013	119	301	16.3	7.4	22.5
2014	187	193	12.44	3.1	15.0
2015	75	191	9.9	5.1	14.9

Here we provide an overview of the regions where animal-borne observations can make significant contributions to the GOOS. The Table below shows priority regions, the animals that can carry sensors to collect oceanographic observations and the questions the observations can contribute to answering.

Table acronyms: Antarctic fur seals - AFS, Ross seals - RS, Southern Elephant seal - SES, Weddell seals - WS, Emperor penguin - EP, King Penguin -KP, Olive Ridley Turtle - ORT, Logger-head turtle -LHT, Leatherback turtle -LT, Flatback turtle (FBT), Green Turtle (GT), Hawksbill turtle (HBT) Whale Shark (WS), Ringed seals (RgS), Bearded Seals (BS)

Focus Region	Forecast	Ocean Dynamics	Behaviour	Active animals	Seasonal coverage✓
NW Shelf	✓	✓	✓	FBT, GT, LHT, HBT	✓
Antarctic Polar front	✓	✓	✓	SES, KP	Mar-Oct
Marginal Ice zone	✓	✓	✓	RS	
Indonesian throughflow	✓	✓	✓	ORT, LHT, LT, FBT, WS	
Antarctic shelf	✓	✓	✓	SES, WS, EP	Mar - Oct
Gulf of Carpentaria (GoC)	✓	✓	✓	ORT, FBT, GT	✓
Meso-scale features	✓	✓	✓	All	
Marginal seas and boundary currents of all oceans.	✓	✓	✓	Sharks, suitable teleosts (swordfish), Turtles	
Tidal glacier fronts and inshore coastal areas	✓ (minor)	✓	✓	Arctic - RgS, BD	July - Apr

Pelagic - drift ice areas	✓	✓	✓	Arctic - HS, HdS	July - Apr

Species, Sample size and Sensors

1. Species

The type of oceanographic data and region covered by marine animals varies depending on the taxon and their life history characteristics, with different advantages and disadvantages to the various species. While some species (e.g. elephant seals) range over ocean basins, routinely diving beyond 600m, other species remain coastal and may only sample the first 100 m of the water column. Oceanographic data have been collected using a wide range of marine vertebrates including seabirds, sharks, turtles, and other fish (fig 1). But the most effective taxon has been pinnipeds, and within this group it is the Phocid or true seals that have contributed the most reliable and consistent data.

Phocid seals are large, and are readily captured and handled, and they carry tags well. More importantly, the tags are easily glued to the hair with epoxy. Seals are particularly well suited for tag deployments because they are large and, due to the lack of land predators, are easily approached and captured for tag deployment. While Weddell seals are not as deep a diver as elephant seals they often dive to the bottom along the continental shelf. They also tend to be more limited in their movements, generally staying within a few 100s km of the tagging location within coastal inshore regions. Finally, while crabeater seals are the shallowest diving of the three, they move extensively around the continental shelf, remaining in the pack-ice almost exclusively thereby sampling environments not well covered by the other species. Phocid seals have also been used to sample the Arctic, with tags being deployed on bearded, ringed, hooded and harp seals (Lydersen et al. 2004, Grist et al. 2011, Grist et al. 2014). Again, these animals exhibit different dive and movement patterns, with the hooded seal being the deepest diver. Sampling in the Arctic has also been accomplished using Narwhals and Beluga whales (Lydersen et al. 2002, Laidre and Heide-Jorgensen 2007, Isachsen et al. 2014). Grey and harbor seals have been used to collect oceanographic data in the temperate regions of the North Atlantic, and North Pacific Oceans and elephant seals have provided significant oceanographic data from the North Pacific (Boehlert et al. 2001, Treasure et al. 2017, Keates et al. 2020).

Sea lions and fur seals (Family Otariidae) have also been used to collect oceanographic information. Sea lions and fur seals are particularly appropriate to sample coastal waters along both coasts of South America, the Galapagos Islands, Southwest Africa, the West Coast of North America across the Aleutian Islands to the northern reaches of Hokkaido Japan (Weise et al. 2010). They are also well suited for sampling the coastal zone of the South Island of New Zealand, the sub-Antarctic Islands and the southern coasts of Australia (Lowther et al. 2013, Foo et al. 2019). While pinnipeds provide excellent coverage of many temperate and polar regions of the world, with the exception of the Galapagos, there are few if any pinnipeds that are accessible for oceanographic sampling. Sea lions are particularly useful in this regard and many species feed benthically, and therefore sample the full depth of the water column.

Seabirds have also proven to be effective platforms for ocean sensing. King Penguins traveling from colonies on the sub-Antarctic Islands have provided extensive temperature profiles of the Southern Ocean (Charrassin et al. 2004, Scheffer et al. 2012, Scheffer et al. 2016). Penguins from temperate regions of the Southern Hemisphere may also provide opportunities to provide temperature and other oceanographic data, albeit primarily in the top 100m. Flying seabirds have great potential to provide surface measurements such as ocean currents and winds (Yoda et al. 2014, Yonehara et al. 2016, Goto et al. 2017) over great expanses of the topical and temperate oceans. However, the kinds of instruments they can carry are limited given small size and weight restrictions associated with flight. Seabirds are a potential underutilized platform for the collection of oceanographic data as seabird colonies can be found in most oceans and regions of the world.

Sea turtles, sharks and large bodied fish, can be used to obtain oceanographic data in the temperate to tropical regions of the world (McMahon et al. 2005, Thums et al. 2018, Andrzejaczek et al. 2019) integrating information from important EOVs/ECVs from areas of interest to biodiversity (Miloslavich et al 2019).. Indeed, data (Temperature-Depth profiles) collected by loggerhead turtles were integrated in ocean nowcast/forecasts that greatly improved the representation of mesoscale eddies and front variations in the Kuroshio-Oyashio Confluence region around Japan (Miyazawa et al. 2019). Moreover, Temperature-Depth profiles collected by olive Ridley turtles were assimilated into an operational seasonal prediction system of regional sea surface temperatures in the Arafura Sea (Doi et al. 2019).

2. Sample size

Central to filling existing data gaps is determining priority regions and the number of sensors (or animals), which need to be deployed. An important consideration here is animal ethics and welfare of tagging marine animals, which have been discussed in detail elsewhere (Sequeira et al. 2019). The optimal sample size for any study is a balance that: (1) allows for appropriate spatio-temporal coverage, (2) provides sufficient statistical power and (3) prioritises animal welfare (*i.e.* not using an excess of animals, and using tags appropriate to the size of the species). The network will have an ethics welfare committee to provide advice on these issues. It should also be noted that each national or institutional component of the network will require ethics approval from their home institutions.

The main contributions of our network will be to fill current observational gaps and complement existing sampling networks such as Argo. As such, the sampling regime will be determined largely by identifying those regions where sampling is poor or non-existent to define where sampling will occur, and therefore which species will most appropriately provide the data required (March et al 2019). The network will fill these observational gaps through proposing new regional tagging programs, initially primarily through leveraging off existing national programs/assets as is typical for the existing networks.

3. Sensor characteristics

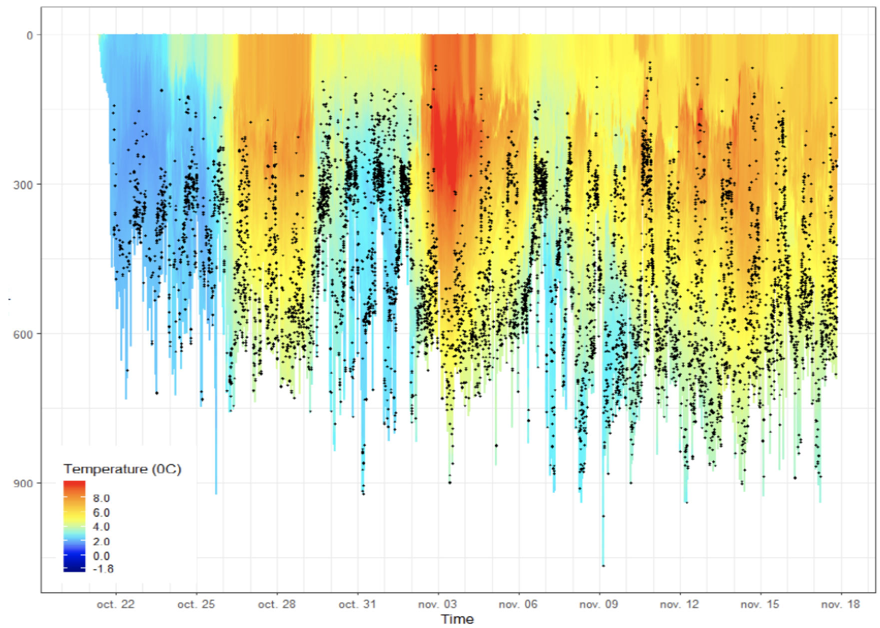
Core Oceanographic Sensors

Over the last fifteen years animals have been instrumented with CTD-SRDL tags to measure the vertical water profiles of temperature and salinity in the top top 2000mThe CTD-SRDLs are built by the Sea Mammal Research Unit (SMRU, University of St Andrews, UK), incorporating CTD sensors developed by

Valeport Ltd (Devon, UK). The sensor head consists of a pressure transducer, a platinum resistance thermometer, and an inductive cell for measuring conductivity. The temperature and conductivity sensors have a precision (repeatability) of 0.005 °C and 0.005 mS/cm, respectively. Before being taken into the field, devices are calibrated in the laboratory by Valeport (Boehme et al. 2009, Roquet et al. 2014). Recently the accuracy of the instruments has been improved by using a correction from the high resolution recovered data which is available to us when the instrument is recovered, the accuracy of the temperature measurements is +/- 0.04 degrees C and salinity to +/- 0.03 g/kg. Moreover, recent adjustments accounting for the thermal mass of the instrument have been investigated which has led to improvements in the salinity measurements but as yet there is still scope for improving the effects of instrument thermal mass on temperature (Mensah et al. 2018). A detailed description of the instruments and oceanographic sensors can be found in Boehme et al. (2009).

New Oceanographic sensors

Other parameters are currently measured or are likely to be realized in the near future. Some tags can measure fluorescence to estimate chlorophyll-a concentration within the euphotic layer, the most commonly sampled biogeochemistry parameter. Oxygen sensors were successfully incorporated into CTD tags deployed on southern elephant seals (Bailleul et al. 2015) and sea turtles. New small size, low energy consumption oxygen sensors were recently developed, and could be easily incorporated into oceanographic tags deployed on marine animals. Oxygen measurements might, for instance, be of a particular importance in monitoring the extent of Oxygen Minimum Zones in tropical seas. Acoustic, acceleration and magnetometer measurements have been used to estimate wind speed, sea state and wind direction (Cazau et al. 2017a, b.). Currently, onboard processing of acoustic signals are being developed and implemented to estimate wind speed in the open ocean. Indeed, ocean wind and surface current have been estimated successfully by deploying GPS on soaring seabirds (Yoda et al. 2014, Yonehara et al. 2016, Goto et al. 2017). Research is being conducted to implement a pH sensor in tags deployed on free ranging animals, but they are still major calibration issues associated with drift over time to be overcome.



The Vertical distribution of prey capture attempts detected by accelerometers (black dots) along the track of a female elephant seal from Kerguelen Island overlaid with the temperature records. This illustrates how physical and biological observations can be integrated to provide unique insights into oceanographic, behavioural and predator-prey processes - an ability unique to the network. Source: C. Guinet, CEBC/CNRS.

Many ecological parameters can be assessed from tags deployed on animals as they provide a direct way to investigate i) the link between physical oceanographic processes and biological ones at meso and sub-mesoscales and ii) how the physics structure biological fields horizontally and vertically. They provide information on EOVs/ECVs in areas and corridors of great importance to biodiversity (Harcourt et al 2019, Hindell et al 2020). Prey field abundance and vertical distribution can also be assessed along the track of marine animals equipped with acceleration sensors (Cox et al. 2018), which detect prey capture attempts. Direct visual observations can be obtained from animal-borne video systems (Davis et al 1999, Hooker et al. 2002, Watanabe et al 2003). This information is particularly valuable when it is related to simultaneous measurements of other parameters such as temperature, salinity and phytoplankton concentrations (Naito et al. 2013; Guinet et al. 2014). Intermediate trophic levels are now being assessed by a broad range of techniques such as the monitoring of bioluminescence (Vacquié et al. 2017) and/or the deployment of very high frequency active acoustic devices (microsonar) to monitor the abundance, size, and reflectance of biological particles within the water column (Goulet et al. 2019). While many of these technologies are novel, the promise of expanding the scope of observations is stimulating much research development and it is anticipated that as these new technologies are adopted the information they provide will become increasingly mainstream.

The ethics of animal oceanographers

The use of animals to collect oceanographic data is truly a "win-win" situation, as it provides data essential to their conservation and management while also providing oceanographic data that would be hard, if not impossible to collect through traditional means.

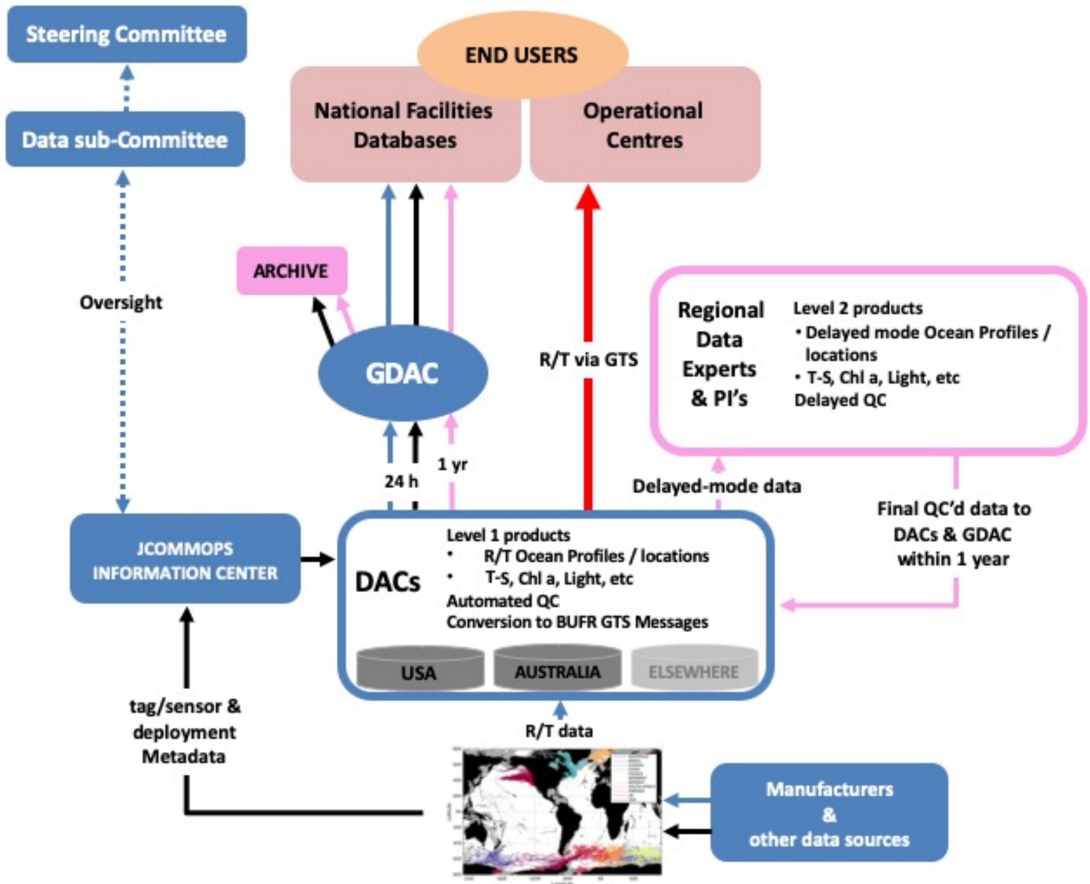
Central to the ongoing success of the network is ensuring best animal handling practice that minimizes negative effects on animal welfare. To ensure that animal welfare is prioritized an Ethical Advisory Board has been constituted (see Ethical Advisory Board below). The primary focus of the board is to provide the ethical oversight of the network activities involving the handling of animals and attachment of sensors.

Our community has been proactive and already much has been done to ensure animal welfare is at the core of our activities. This has been done through publishing a number of standard operating procedures that describe in detail the capture, handling, instrument attachment, and care of animals (McMahon et al. 2000, Field et al. 2002, Hawkins 2004, McMahon et al. 2008, Field et al. 2012, McMahon et al. 2012, Horning et al. 2019). However, given the potential for the expansion to a broader range of species and the development of new sensor packages we as a community are committed to maintaining that best practise in maintained and we will do this through ongoing researching into upgrading capture, handling and attachment methods as well as quantifying the effects of carrying instruments has on animal behaviour, performance and vital rates.

Data Management

A key requirement of the Network is to ensure quality-controlled, interoperable animal-borne ocean sensor data and metadata that are disseminated regularly in a coordinated manner to the global oceanographic community for real-time assimilation by operational models, and for use by the broader research community as well as for education and public outreach. The Network's data management will be directed by a Data sub-Committee, charged with developing a strategy and implementation plan for international coordination and governance of the Network's data and metadata (see Implementation 4 b. For details).

We envision a data flow structure, somewhat guided by the Argo approach, but recognising the unique aspects of the Network's data and metadata and the comparatively small scale of our network requiring some simplification. Oversight will rest with the Data sub-Committee, which includes representatives of the major tag manufacturers, data management specialists and end-users, in coordination with JCOMMOPS, and under the guidance of the Steering Committee. The network's data flow originates with the tag manufacturers, who have well-established infrastructures for decoding, archiving and serving data to their customers. Data flow and management will follow accepted community (oceanography and also animal tacking) standards for the data flow from tags to repository (Sequeria et al In Prep.). Principal investigators (PI's) who purchase and deploy tags on animals will have the option of sharing location and sensor data with the Network, and these PI's will provide metadata about tag deployments (*e.g.*, location, date, species, tag programming). Additional tag metadata (*e.g.* sensor sensitivities and calibrations, factory programming defaults, firmware version) will be obtained directly from the tag manufacturers (black lines in the data flow schematic). Real-time data are sent to the regional Data Assembly Centres (DAC's) where automated processes will be used to: 1) standardise the data and metadata in agreed upon formats (see below); 2) conduct preliminary quality control of the data; 3) generate Level 1 products - initially ocean CTD profiles; 4) convert Level 1 products to BUFR messages and transmit via the GTS to operational centres for real-time assimilation (within 24 h; red line in the data flow schematic). Metadata will be monitored by the JCOMMOPS Information Centre and where, for example, missing WMO identification numbers will be assigned to tags prior to their deployment. Level 1 products and metadata are also sent within 24 h to a Global Data Assembly Centre (GDAC), where additional scrutiny can be applied to the data quality control, e.g., erroneous profile and location data may be corrected, prior to public internet access by end users, national research facilities, and aggregated databases. The GDAC is maintained by all DACs together, under the umbrella of AniBOS, with a unique database maintained and funded jointly by the members of the AniBOS network and a high level of data format standardization decided early on in the process will make complete metadata (e.g., compliant with the ISO 19115 standard for geographic metadata) publicly discoverable, downloadable and queryable via interoperable web services, such as OGC - Open Geospatial Consortium - and DAP - Data Access Protocol - services.



A schematic illustrating the proposed flow and uptake of AniBOS data

Data flow in AniBOS. Data are owned by the PIs of projects buying and deploying the instruments. Using the fact that raw data are decoded, stored and managed by the manufacturer of loggers, we will obtain the data directly from manufacturers provided the PIs agree to share their data. To ensure homogeneity in the metadata, JCOMMOPS will provide a platform to centralize identification, calibration and deployment information that can be accessed by PIs, manufacturers and data centers. Data is gathered and processed in real-time (R/T) mode by regional data centers (DACs). Each DAC is responsible for the R/T transmission to the Global Telecommunication System (GTS) for operational applications. However active collaboration between the different DACs will be pivotal to the success of AniBOS. A "virtual" Global Data Center (GDAC), jointly operated by the regional DACs, will assemble data from the different DACs in one single data repository, forming the real-time "level 1" AniBOS data product. A delayed-mode "level 2" data product will then be produced (yearly release is targeted), benefiting from the input of regional data experts, PIs, manufacturers and data experts collaborating to the network AniBOS. The data sub-committee of AniBOS will supervise this work in association with the DACs.

Delayed-mode quality control of location and ocean profile data will be conducted by regional data experts and participating PIs, ideally within 1 year of tag deployment end dates. These delayed-mode quality control (DMQC) processes will be standardised globally, using the Level 1 product built by the GDAC as the reference dataset onto which editing, re-calibration and data adjustment will be applied. The DMQC will be building upon the set of similar procedures that have been developed in the past within the framework of MEOP or by the different national teams. New methods will have to be developed as well, in particular when new loggers and new sensors become available. The GDAC will make all Level 2 data publicly available and archive the data, e.g., with the NOAA/National Centers for Environmental Information (NCEI) and the Australian Ocean Data Network (AODN), IMOS.

Currently, the IOOS-Animal Telemetry Network (ATN) and the AODN serve as regional DAC's for the US and Australia, respectively. The Ocean Tracking Network (Canada) could act as an additional DAC, serving Canada, Europe and other regions. The ATN could also provide the required infrastructure to run the GDAC. This potential structure will need to be explored further and depend on existing resources.

Standardised data and metadata

Standardised data and metadata formats are required for inter-operability with other ocean observations arising from remote sensing orother *in-situ* platforms such as drifters and gliders. Two types of format will be required, to store either time-referenced data or profiling (depth-referenced) data. The Argo data management group develops and maintains such formats (http://dx.doi.org/10.13155/29825), with data files written with the netCDF format following the standardized Climate and Forecast (CF) specification. The Sea-Mammals netCDF data formats, currently used to store and distribute data in the MEOP databases (http://www.meop.net/database/format/) has been adapted from the Argo data profile and trajectory formats. These formats are extremely popular among the community of physical and biogeochemical oceanography and in operational centers, however adaptations will be required to encompass the specificities of animal borne ocean sensors. The time-referenced "trajectory" format in particular may require important modifications, but other specialized formats exist or are being developed that could offer a robust alternative.

The NASA/JPL Oceanographic *In-situ* data Interoperability Project (OIIP) has progressed interoperability for marine animal tagging data through their development of the netCDF electronic tag data template specification (nc-eTAG, Tsontos et al. 2020). These templates are applicable to a broad spectrum of data types and sensor measurements. A parallel data standardisation initiative is being run through the proposed Global Ocean Observing System- Animal Research and Tracking Initiative (GOOS-ARTI), which could inform an expansion of the OIIP-led standard to encompass satellite-based location (Argos and GPS), ocean observing tags that are more commonly deployed on air breathing species such as seals, seabirds, and sea turtles. In collaboration with the OIIP, the GOOS-ARTI, the International BioLogging Society (IBioLS) and tag manufacturers, the Data sub-committee will strive to adopt and enhance the nc-eTAG templates. The specific areas of enhancement include: 1) refining the specific domain metadata elements for inclusion as global attributes in the data files based on further community input and their disposition as Required, Recommended, Optional, and 2) establishment of controlled vocabularies for these various tag domain metadata to ensure semantic interoperability.

The OIIP standard includes rich geospatial metadata, encompassing the following information: *device type* (e.g., manufacturer, model, serial number), *ownership* (e.g., country, program, PI, contact details), *device programming* (e.g., firmware version, sampling rate), *platform deployment* (e.g., species, life history characteristics, deploy location, date, attachment method), *sensors* (e.g., type, accuracy, precision, calibration), *recovery* (e.g., location, date). Each category has sets of required, recommended and optional attributes classed with groups conforming to the above categories. Given the broad diversity of potential tag and sensor packages that can be deployed on animals for ocean observing, the Data sub-committee will similarly collaborate with OIIP and tag manufacturers to further develop the metadata structure as needed. The sub-committee, additionally, will liaise with JCOMMOPS to ensure mandatory metadata conforms to JCOMMOPS guidelines to facilitate international monitoring by JCOMMOPS and interoperability with other GOOS networks.

To the extent possible, we will ensure metadata flows directly from the tag manufacturers to JCOMMOPS and the DAC's. However, not all tag manufacturers will be able to comply with this approach, and alternative yet similarly robust methods will need to be explored for harvesting metadata in these cases.

Data accuracy and precision

In the case of sensor metadata, we aim to ensure that all sensor accuracy/precision and calibration attributes are recorded to ensure appropriate handling during QC and creation of derived products. The minimum precision associated with the data provided by a tag is critical and will vary depending on manufacturer and tag type. Similarly, measurement accuracy will need to be specified for all datasets (e.g. location, temperature, salinity, chlorophyll-a). Rather than imposing strict minimum thresholds on sensor accuracy and precision, this approach will allow greater assimilation of observation data sets across diverse tag types. To ensure consistent data quality across platforms we will adopt the Argo flagging system (Argo data management, doi: http://dx.doi.org/10.13155/33951) and these are summarised as follows:

Flag	Interpretation	Real-time comment	Delayed-Mode meaning
0	No Quality Control	No QC done	No QC done
1	Good data	Real-time QC tests passed	The adjusted values are statistically consistent and accompanied with an error estimate
2	Probably good data	Data are probably good and pass RT-QC tests	The adjusted values appear to be statistically consistent and are accompanied with an error estimate

3	Probably bad data	One or more RT-QC test is failed, but maybe be corrected in delayed mode	Post adjusting the data are not statistically stable and don't have accompanying error estimates
4	Bad data	One or more RT-QC test is failed	Data can't be adjusted
5	Value changed	Value changed	Value changed
6	Not Used	Not Used	Not Used
7	Not Used	Not Used	Not Used

Data Quality Control (real-time and delayed mode)

Two levels of quality control (QC) will be applied to the data in real-time and in delayed-mode. The specifics of these procedures will be detailed in a document similar to the Argo Data Management, Argo Quality Control Manual. For Level 1 real-time data and products, all real-time quality-controlled processes will be implemented automatically and will be consistent with quality-control procedures developed for XBTs, Argo floats and gliders. Quality-control and interpolation processes will be applied to horizontal location and vertical sensor data to clearly flag observation quality and ensure that implausible measurements are identified and corrected, when possible.

Level 2 delayed-mode CTD data products will be adjusted, edited and quality-controlled using established protocols developed by the Marine Mammals Exploring the Oceans Pole to Pole (MEOP) program (Siegelman et al. 2019 JAOT). Analogous processes have been developed for QC'ing horizontal locations and will be established for other sensor data and equipment manufacturers. This QC will be more comprehensive, with manual intervention as required, and carried out by regional data experts in accordance with standards adopted by the Data sub-committee.

Data interoperability & integration

In addition to the data and metadata standardisation approach described above, all data products produced by the Network will be available in a format compatible with the other GOOS Networks to global ocean observing capacity. In most cases, we envision that our adoption of the OIIP-developed nc-eTAG netCDF standard should be sufficient to achieve full interoperability and integration with the other networks. The Data sub-committee will continually monitor interoperability and integration and adapt data standards of device translation methods to ensure complete integration of the Network's data products.

Data Archival and Preservation

We will explore secure archiving of data with the National Centers for Environmental Information (NCEI) at NOAA in the US. This is the archive for the US Animal Telemetry Network's data and would ensure long-term, secure preservation of data, metadata and provenance information. Additional storage facilities are available through the Australian Ocean Data Network, IMOS, Australia and potentially through the Ocean Tracking Network, Canada. In all cases, the data will adhere to the Open and FAIR principles of findability, accessibility, interoperability and reusability.

Impact of the AniBOS network on society

The advance of human technologies has made the ocean the next great frontier for industrial development (McCauley et al., 2015; Ogburn et al., 2017; World Economic Forum, 2017). For this "Blue Economy" agenda to be sustainable, and to ensure that rapidly expanding marine developments do not compromise the existing socioeconomic benefits and essential ecosystem services humanity derives from the ocean, managers and policy makers need to be informed by comprehensive monitoring of the ocean. We foresee the following groups will directly benefit from the information gained from these observations, especially given the data we collect are freely available to the global community.

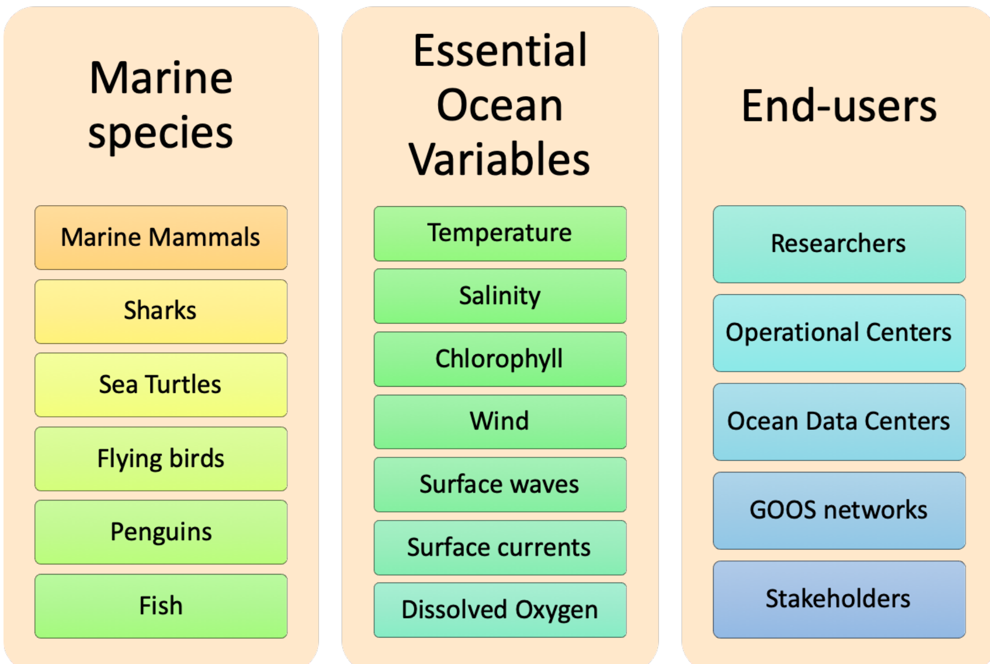
- The blue economy
- Operational ocean and weather forecasting organisations
- Indigenous peoples
- Marine conservation and living resource management
- Marine ecologists
- Physical and biological oceanographers
- Climate change researchers (including climate projections, impact assessments, social stuff)
- Policy makers
- Educational institutions

Network design to deliver on the objectives

AniBOS will be a global network and welcome contributions from all of the world's oceans, but with an emphasis on currently under-sampled regions. The network will engage with other groups to identify best regions in terms of ocean dynamics.

AniBOS will focus, at least in the beginning, on the use of animal borne sensors to gather data on the physical and biogeochemical state of the ocean. The schematic below lists the main marine species group that are currently being used to gather such data. Strong constraints exist on the type of logger that one can use depending on the species considered. With the technology currently available, marine mammals and particularly elephant seals have been by far the most successful species used to gather ocean data. The use of sea turtles in tropical regions is also rapidly developing, contributing to monitoring the upper ocean heat budget.

A number of Essential Ocean Variables can be monitored using animal borne ocean sensors. The measurement of temperature and salinity vertical profiles is currently the most mature and it is foreseen that it will remain a central activity of AniBOS, as these two variables play such a central on the ocean dynamics and provide key information about the state and circulation of the oceans to which all aspects of the marine environment are intimately enslaved. Chlorophyll sensors are now widely deployed, while dissolved oxygen sensors are being developed. The measurement of other variables such as wind, surface waves or surface currents are more in a pilot phase, but with large potential in the future.



Education and outreach

Animal-borne sensors are ideal platforms for education and outreach activities and for more general communication of science to society, from the classroom and kids to citizens. The "Follow the Glider" initiative - http://followtheglider.socib.es, using gliders could be used as an example. It is a web-based educational tool aimed at students and teachers. We are currently working with Vardis Tsontos, NASA/PODAAC,Jet Propulsion Laboratory to develop an interactive web platform to visualise and interact with animal-borne CTD datas sets.

Early career researcher engagement

Ongoing longevity of the program will rely on successfully retaining young researchers and recruiting them into research leadership roles. Therefore, providing Early Career Researchers (ECRs) with skills and experiences that will help foster such development will be a focus for the network. The current professional cohort (scientists and technical staff) has an important role to narrow knowledge gaps, through the transfer of skills and expertise, and mentor and guide the next generation of researchers and scientists. To facilitate this AniBOS will:

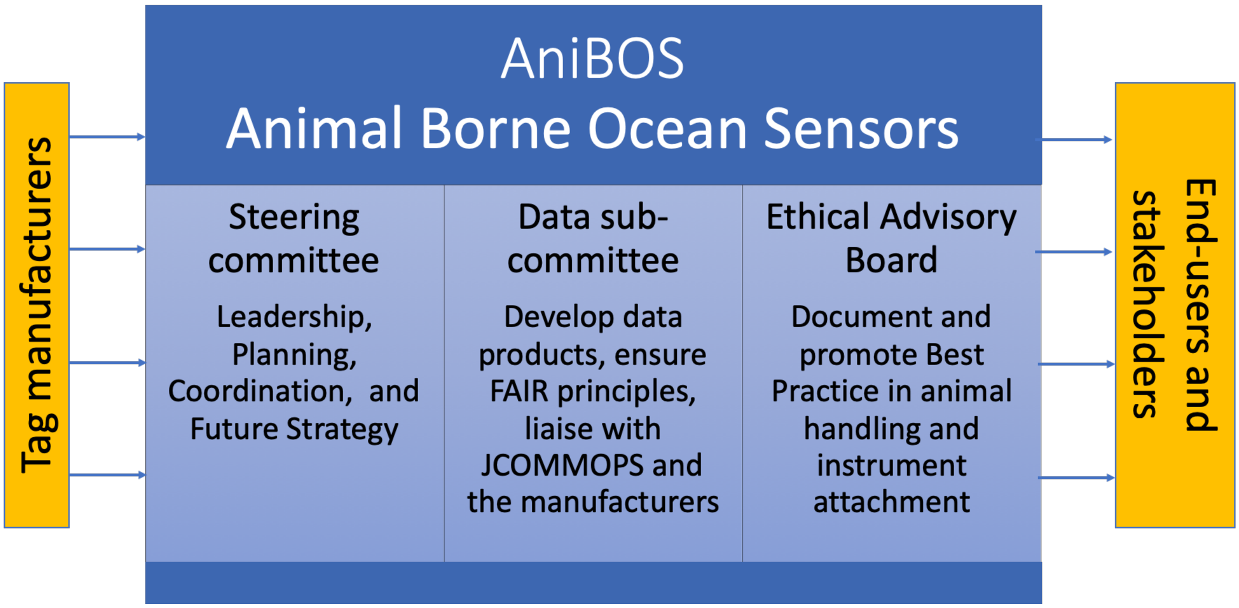
1. Prioritise support for researchers in the early stages of their careers
2. Work with ECRs to determine and develop career pathways in research
3. Provide an environment with balanced workloads
4. Engage with ECRs in developing grant proposals to national and international funding agencies
5. Promote collaborations and facilitate ECR memberships on national and international advisory boards and scientific committees
6. Seek and provide salaries and stipends as a high priority
7. Deliver advice and information through the development of a mentorship program to support ECRs

Cross-network collaboration and communication

The Global Ocean Observing System (GOOS) is a sustained collaborative system of ocean observations, encompassing *in situ* networks and satellite systems that work collaboratively to provide the global operational and research communities with information from across the world's oceans. Our contribution will be to provide oceanographic observations that extend the coverage of existing networks that compliments data that are already being collected. We will do this by making the data freely and easily available to the scientific community in both raw and quality controlled form (see Data Management section below). The network will also contribute via membership of key observing system committees and bodies including the Observation Coordination Group (OCG). Through membership of the OCG we will, along with the other networks within the OCG, actively participate in providing: 1) input and advice to reports on key OCG activities; 2) metrics on the effectiveness, coordination and operation of the Observations work programme, performance as measured against requirements, delivery of raw data, marine telecommunications, measurement standards, logistics and resources.

Implementation

1. Overall Management structure



2. Network Terms of Reference (ToRs)

1. Develop an Implementation Plan for a global network of ocean profiling (e.g. temperature, salinity, chlorophyll) animal-borne sensors, to contribute to an integrated Global Ocean Observing System
2. Grow the existing international consortium, to undertake the implementation and maintenance of the global network
3. Provide scientific information to and receive advice from Observations Coordination Group (OCG) and Global Ocean Observing System (GOOS) on scientific and technical issues to ensure sustained observing
4. Evaluate observing network coverage to guide the long-term development and evolution of the network
5. Provide advice and guidance on technical (sampling tools and sensors) innovations relevant to the network, including development of best practices for sampling design and delayed mode quality control.
6. Promote and maintain highest levels of best practise in animal welfare
7. Facilitate delivery of Real Time data to the GTS and Delayed Mode data to an agreed global data centre for the network

8. Adhere to and promote FAIR and Open data principles
9. Liaise with other in situ ocean observing networks including: ARGO, the ship-of-opportunity program, the tropical atmosphere-ocean array, and remote sensing program such as Topex/Poseidon and Jason.
10. Provide as appropriate reports on progress to the OCG and input to OCG forum meetings

3. Steering Committee (SC) Terms of Reference (TOR)

A. Steering Committee membership (max=12)

The Steering committee will comprise 12-15 members and be led by two co-chairs. Where possible, the Committee will have a balance across geographic representation, gender, career status, community representation and expertise. In particular, the Committee should encompass expertise in:

I. Physical oceanography
II. Animal tracking (seals, sharks, turtles)
III. Data management
IV. Regional oceanographic representation and representatives from the following communities:
V. GOOS/JCOMMOPS/OCG
VI. CLS Argos
VII. Instrument manufacturing

The initial SC elected at the workshop is:

Co- Chairs:

I. Fabien Roquet (Oceanography) & Clive McMahon (Ecology)

Members:

II. Melinda Holland (Industry)
III. Sophie Baudel (Argos)

B. Steering Committee election

The initial SC will be elected through nomination from the community and the nomination seconded from the floor. Under circumstances where there are multiple nominations the decision will go to a ballot. Vacant positions – may be filled out of session.

C. Tasks

The specific tasks of the SC include:

I. Provide leadership to implement the observing network
II. Coordinate network activities including deployment regimes
III. Write, Review and submit the scientific and operational plans of the network to GOOS OCG
IV. Assist the co-chairpersons in the preparation of reports, reviewing action items of previous meetings and report these to the broader community
V. Ensure and build stakeholder engagement

VI. Promote broad international involvement, enhance coordination and collaboration to achieve integrated and sustained observations to end-users globally.

D. Membership term lengths

Typically, members would serve for one term of four years, but members may in principle be eligible for **one** subsequent term.

4. Data Subcommittee

A. Data Sub-committee membership (max=12)

The Data Subcommittee will comprise 10 expert members and be led by a chair. Where possible, the Subcommittee will have a balance across geographic representation, gender, career status, community representation and expertise.

The initial Subcommittee Elected is as follows

Chair:

Ian Jonsen (MQU)

Members:

MEOP / Fabien Roquet

JCOMMOPS / Kevin O'Brien

IMOS / Fabrice Jaine

AODN / Seb Mancini

ATN / Megan McKenzie

BCG / Christina Schallenberg (to be invited)

OTN / Jon Pye (to be invited)

Wildlife Computers representatives (to be invited)

SMRU representative (to be invited)

NCEI / Melissa Zwang (to be invited)

B. Tasks

The specific tasks of the Data Subcommittee are to develop a strategy and implementation plan for international coordination and governance of the Network's data and metadata. The Subcommittee will be responsible for solving issues that hinder true interoperability of animal-borne sensor data and metadata, regardless of species, tag/sensor manufacturer and type, deploying Regional or National Facility and deployment location. The subcommittee will, in general, also oversee the data adherence to FAIR and Open data principles (Findable, Accessible, Interoperable, Reusable) i.e.:

a. Fair - Data and supplementary materials have sufficiently rich metadata and a unique and persistent identifier.
b. Accessible - Metadata and data are understandable. Data is deposited in a trusted repository
c. Interoperable - Metadata use a formal, accessible, shared, and broadly applicable language or knowledge representation and
d. Reusable - Data and collections have a clear usage license and provide accurate information on provenance.
e. Open - Data can be used, reused and redistributed by anyone, subject to appropriate attribution and sharing in the same manner they appear.

C. Data Subcommittee election

Typically the data subcommittee will be elected through nomination from the community and the nomination seconded from the floor. Under circumstances where there are multiple nominations the decision will go to a ballot. Vacant positions – may be filled out of session.

D. Membership term lengths

Typically, members would serve for one term of four years, but members may in principle be eligible for **one** subsequent term. Initial members will serve terms of either two or four years so that term expiries are staggered, ensuring a continuity of experience on the subcommittee.

5. Ethical advisory board

A. Ethical advisory board membership

Animal welfare and best animal handling practice is a core concern for the network and to ensure compliance across the network membership we will constitute an ethics subcommittee.
The Ethical advisory board will comprise 6-8 expert members and be led by a chair. Where possible, the board will have a balance across geographic representation, gender, career status, community representation and expertise.

B. Tasks

This subcommittee's primary responsibilities will be to:

1. ensure that the use of animals is justified, provides for the welfare of those animals and incorporates the principles of Replacement, Reduction and Refinement (the 3Rs).
    a. Replacement - techniques that replace the use of animals must be sought and used where possible
    b. Reduction - each project must use no more than the minimum number of animals necessary and
    c. Refinement - projects should be designed to avoid pain and distress in animals
2. on behalf of the network, ensure that all activities relating to the care and use of animals comply with and are conducted in accordance with world's best practice and in compliance with local legal requirements
3. review proposals from prospective members wishing to join the network to ensure that the proposal meet the stringent compliance standards of network on the use of animals for scientific and observational purposes
4. provide ongoing feedback to the network membership on advances in best practise and facilitate the adoption of these where appropriate

C. Ethical advisory board election

Typically the data subcommittee will be elected through nomination from the community, where there is considerable expertise and experience around animal welfare and best animal practice, and the nomination seconded from the floor. Under circumstances where there are multiple nominations the decision will go to a ballot. Vacant positions – may be filled out of session.

D. Membership term lengths

Typically, members would serve for one term of four years, but members may in principle be eligible for **one** subsequent term. Initial members will serve terms of either two or four years so that term expiries are staggered, ensuring a continuity of experience on the subcommittee.

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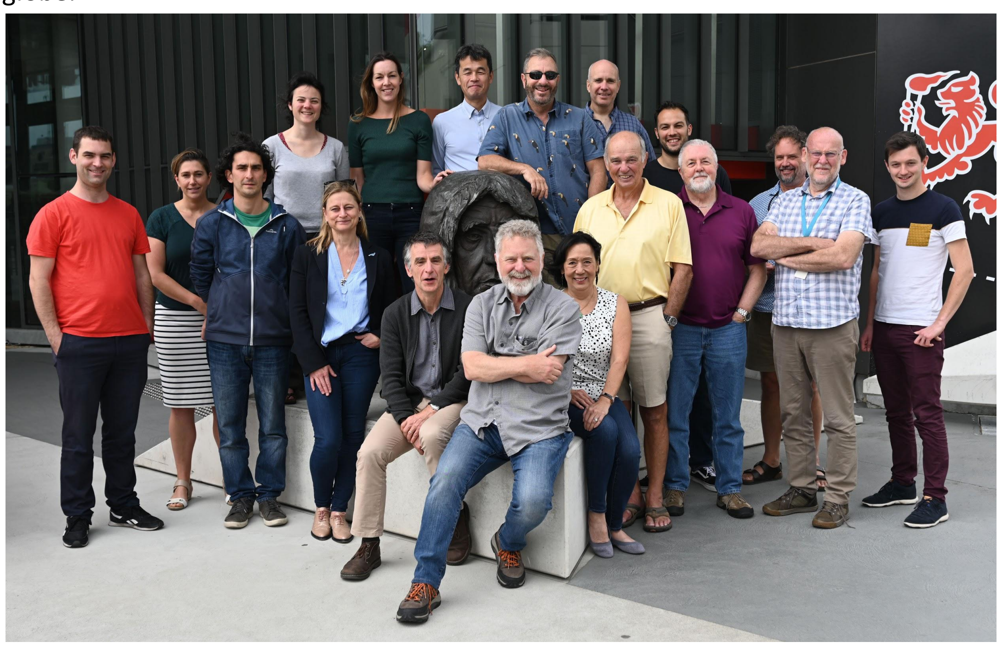
Appendix - Workshop In Hobart

The workshop was funded jointly by the Integrated Marine Observing System and from Antarctic Gateway through the Institute of Marine and Antarctic Science. The main aims of the workshop were to:

1. form the Steering Committee (SC) to oversee the process of establishing the network
2. establish the committee's terms of reference, necessary codes of practice, standardization of procedures and quality control systems
3. form a data subcommittee (SSC) to oversee the data adhere to FAIR data principles (Findable, Accessible, Interoperable, Reusable) i.e.:
    a. Fair - Data and supplementary materials have sufficiently rich metadata and a unique and persistent identifier.
    b. Accessible - Metadata and data are understandable. Data is deposited in a trusted repository
    c. Interoperable - Metadata use a formal, accessible, shared, and broadly applicable language or knowledge representation and
    d. Reusable - Data and collections have a clear usage license and provide accurate information on provenance.

The workshop was held from 19/11/2019 to 21/11/2019 in the IMAS board room and attended by 22 members of the animal-borne ocean sensor community, the United Nations and research institutes from across the globe.



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Countries represented (n=8)
Australia
Canada
France
Japan
New Zealand
Sweden
United Kingdom
United States of America

Workshop Report

The workshop was funded jointly by the Integrated Marine Observing System ($15K) and from Antarctic Gateway through the Institute of Marine and Antarctic Science. The main aims of the funded workshop were to:

1. form the Steering Committee (SC) to oversee the process of establishing the network
2. establish the committee's terms of reference, necessary codes of practice, standardization of procedures and quality control systems
3. form a data subcommittee (SSC) to oversee the data adhere to FAIR data principles (Findable, Accessible, Interoperable, Reusable) i.e.:
    a. Fair - Data and supplementary materials have sufficiently rich metadata and a unique and persistent identifier.
    b. Accessible - Metadata and data are understandable. Data is deposited in a trusted repository
    c. Interoperable - Metadata use a formal, accessible, shared, and broadly applicable language or knowledge representation and
    d. Reusable - Data and collections have a clear usage license and provide accurate information on provenance.

The workshop was held from 19/11/2019 to 21/11/2019 in the IMAS broad room and attended by 22 members of the broader animal-borne ocean sensor community, the United Nations and research institutes from across the globe (see attendees Appendix)

Workshop Outcomes

1. Form the Steering Committee (SC)

The initial SSC co-chairs were elected at the workshop, the co-chairs are; Clive McMahon (IMOS/SIMS) and Fabien Roquet (UG). Advice and direction has been sort from the GOOS (Global Ocean Observing System) Observing Coordination Group on final SSC election rules. The details can be found in the accompanying Proposal that we will submit to the OCG in April 2020 for consideration as an emerging ocean observing network

The SC has prepared a draft proposal that will be disturbed for feedback as follows to ensure that a final draft can be submitted to the OCG as outlined above.

Timelines for proposal preparation, review and submission

- 30 November 2019 – Draft Workshop report distributed to attendees for review
- 04 December 2019 – 1st draft of the Proposal sent to the community31 for feedback by 31 January 2020
- Revisions of draft proposal by SC
- 28 February 2020 – 2nd Draft of the Proposal sent to the community for feedback by 15th March 2020
- 15 March 2020 – 01 April 2020 incorporate community feedback and prepare final draft
- 01 April 2020 – Submit final draft to the OCG for consideration

2. The terms of reference for both the SC and the data subcommittee are detailed in the accompanying proposal
3. A data subcommittee comprised of 11 members chaired by Ian Jonsen has been formed. Membership details, Tasks and Terms of Reference are contained within the accompanying proposal
4. A follow up meeting funded by EMODNET is planned for May/June 2020, the location is yet to be determined but one option may be Genoa, Italy.

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South Africa
Spain
Sweden
USA