Received: 8 May 2024 | Revised: 20 March 2025 | Accepted: 1 April 2025

DOI: 10.1111/csp2.70052

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access

WILEY

PERSPECTIVE

A research toolbox for regional data collection to support the conservation of large batoids: A case study on the critically endangered flapper skate (*Dipturus intermedius*)

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Abstract

Elasmobranchs, specifically skate species (superorder Batoidea), are at risk of extinction, with over one-third currently listed as Endangered, exacerbated due to their k-selected life strategy. A regional conservation approach is required to support the collection of rigorous, species-specific data alongside collaborative efforts across sectors and jurisdictions. Skate species that extend beyond jurisdictional boundaries encounter additional complexities from divergent national legal frameworks, monitoring requirements, and conservation priorities, resulting in inconsistent data collection. Here we present an innovative research "toolbox," initially devised for the Critically Endangered flapper skate (*Dipturus intermedius*) in the North-East Atlantic, but applicable to most demersal elasmobranchs. This toolbox offers a systematic approach (Why, What, Who, Where, and When?) to obtain critical information for the conservation of elasmobranchs, with a focus on standardization and cross-border collaboration. Recent advancements in understanding flapper skate ecology highlight the potential for regional conservation initiatives, emphasizing the importance of coordinated actions, and serve as an illustrative example within the context of the "toolbox."

KEYWORDS

elasmobranch, endangered, guidance, management, policy, protection, sharks

1 | INTRODUCTION

Over one-third of the world's elasmobranchs are now threatened with extinction, with skate (superorder *Batoidea*) at particular risk (Dulvy et al., 2021). This vulnerability has been attributed to several life history traits such as a long lifespan, low fecundity, late maturation, and low intrinsic potential to recover from certain pressures such as fishing (Walker & Hislop, 1998; Stevens et al., 2000; Dulvy & Reynolds, 2002; Butt et al., 2022). Conservation actions are urgently needed for such species if extinctions are to be averted. Given these time constraints, effective management will require robust species-specific scientific evidence, underpinned by cross-sectoral collaboration to direct policy development (e.g., Garbett et al., 2021; Schmeller et al., 2008; Simpfendorfer et al., 2011).

For elasmobranchs, and other wide-ranging species that move across jurisdictional boundaries (e.g., seabirds and marine mammals), these considerations are compounded by differences in national legal frameworks, statutory monitoring requirements, survey effort, and conservation priorities (e.g., Cicin-Sain et al., 1998; Lascelles et al., 2014; Schmeller et al., 2008). Such differences can result in non-standardized data and reporting practices (Isaac et al., 2020; Isaac & Pocock, 2015) preventing comprehensive oversight and appropriate management (Isaac & Pocock, 2015; Kindsvater et al., 2018). Within this overall context we present an iterative "toolbox" that consolidates a range of contemporary practices into a conceptual framework for gathering policy facing data for skate, based on learned experience (Figure 1).

The development of this toolbox arose from the synthesis of a diverse set of research experiences aimed at conserving the flapper skate. The process began with the "Movement Ecology of the Flapper Skate" project, funded by NatureScot and Marine Scotland, which concentrated on the Loch Sunart to Islay Marine Protected Area. The project's scope was broadened subsequently through the EU INTERREG VA SeaMonitor project, which encompassed the Island of Ireland, Western and Northern Scotland, with supplementary data from Southern Norway. SeaMonitor, in turn, served as a mechanism for leveraging additional funding within the project's timeline (2019–2023), supporting complementary research efforts, and a Regional Flapper Skate Working Group (Garbett et al., 2021).

Collectively, these research programs employed a range of techniques, including acoustic and satellite tracking, population genetics, baited remote video surveys, Bayesian distribution modeling and life history and

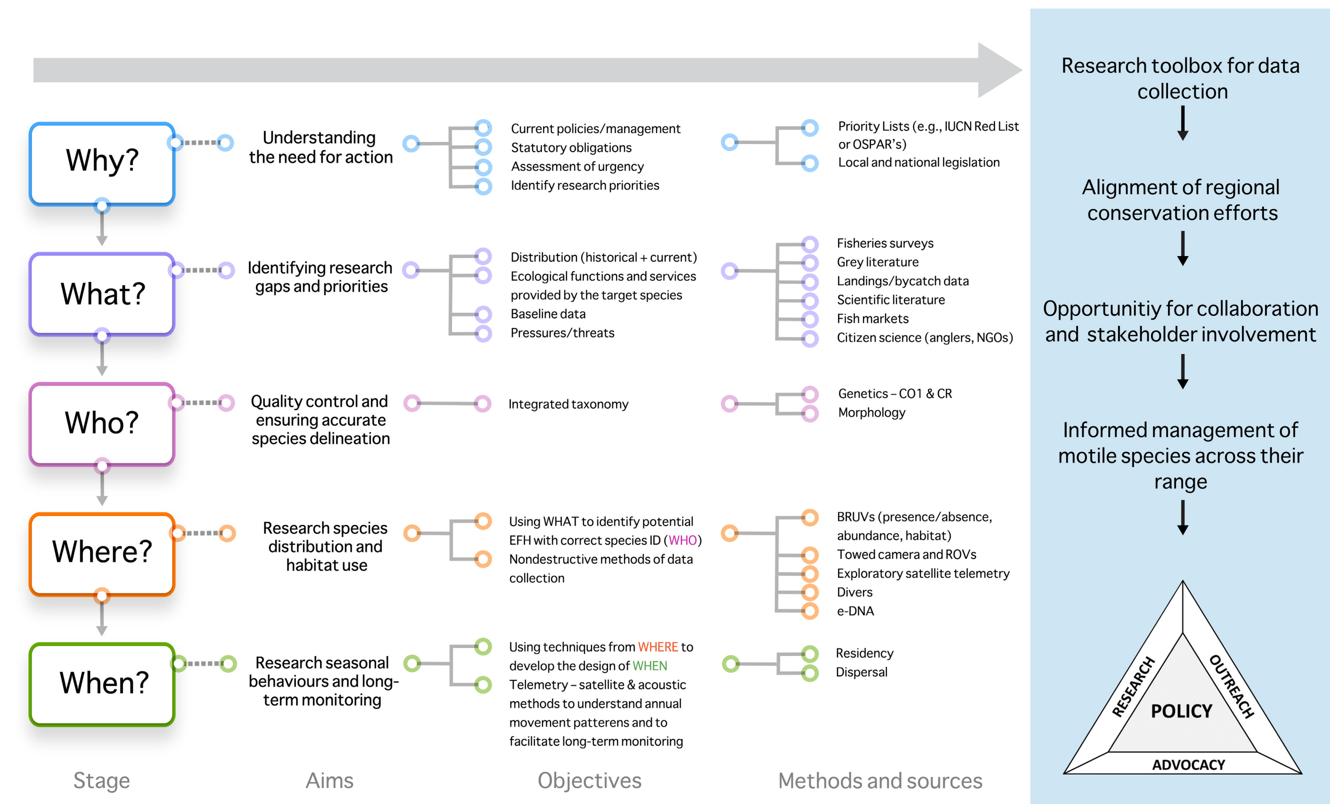

FIGURE 1 The conceptual framework for regional data collection to support the conservation of large batoids.

physiology studies. Unfortunately, the COVID-19 pandemic constrained SeaMonitor's fieldwork to just 2 years (as opposed to the planned four) requiring all research activities to be conducted simultaneously, and with minimal pilot studies. Under less constrained conditions, a more iterative approach, incorporating explicit feedback mechanisms, would have allowed for greater adaptability to emerging information. These insights form the core of this paper, serving to inform data collection strategies for the conservation of other similar marine species. The step-by-step workflow of the "toolbox" (Figure 1) is structured around Aristotle's five axiomatic questions: (*why, what*, *who*, *where*, and *when*?), to streamline current practice, avoid common pitfalls and facilitate collaboration (Aristotle, 350 B.C).

1.1 | *Why* is action needed?

The scale of the ongoing biodiversity crisis necessitates the prioritization of efforts to ensure effective conservation. The first step in the toolbox is to establish the conservation value of the species in question, which can provide the justification, prioritization, and direction for conservation-driven management efforts. Timeliness, or urgency, is paramount, and is best expressed as extinction risk; defined as how likely a species is to disappear under prevailing circumstances (Mace et al., 2008; Martin et al., 2012). If a species is sufficiently threatened, then some form of conservation action is required to prevent its continued decline and eventual extinction (Martin et al., 2012). The IUCN Red List stands as a global authority on extinction risk, which categorizes species according to their threat level, following rigorous assessment (Mace et al., 2008), complemented by regional or national species priority lists (e.g., OSPAR's List of Threatened and/or Declining Species and Habitats). At an actionable level, these resources can inform conservation-facing legislation and direct research efforts (Knight et al., 2008). For example, the flapper skate is classified as a Critically Endangered species on the IUCN Red list (Ellis et al., 2021) and is listed as a high priority species on two regional legislative instruments: Annex V of OSPAR (OSPAR Convention; OSPAR Commission, 2008) and the Helsinki Commission (HELCOM, 2006). In response, the high conservation value of the flapper skate has triggered a swath of fundamental research (Bache-Jeffreys et al., 2021; Barrios-O'Neill et al., 2017; Benjamins et al., 2021; Benjamins, Dodd, et al., 2018; Benjamins, Fox, et al., 2018; Dodd et al., 2022; Frost et al., 2020; Garbett et al., 2021; Garbett et al., 2023; Lavender et al., 2022; Neat et al., 2015; Phillips et al., 2021; Pinto et al., 2016; Régnier et al., 2021; Régnier et al., 2024; Schwanck et al., 2022; Thorburn et al., 2021).

1.2 | *What* do we already know?

Following prioritization, the next step is to ascertain the level of knowledge available for management of the target species, in other words, to establish the known knowns and known unknowns. Effective conservation depends largely on fundamental knowledge such as the species' physiology, ecology, and population demographics (Agardy, 2000; Fox et al., 2012). Much of this information, the "known knowns," can be gleaned from existing sources (Maes et al., 2015), including government-funded surveys (e.g., fisheries management plans, gray literature; Marie et al., 2017; Pennino et al., 2016), fisheries-dependent commercial data (landings, bycatch, markets; Pennino et al., 2016; Karp et al., 2023), scientific research (peer-reviewed publications, unpublished theses), citizen science (sports fishermen, anglers, voluntary conservation groups; Beaudreau & Levin, 2014; Fortibuoni et al., 2017) and from publicly accessible media (books, archived newspapers, club webpages; Moore & Hiddink, 2022). Undeniably, much of our understanding of the flapper skate's distribution has come from indirect sources, such as fisheries stock assessment catch records or georeferenced genetic records, rather than targeted investigation (e.g., see Garbett et al., 2023; Pinto et al., 2016; Régnier et al., 2024). Thorough groundwork in this way not only helps identify sites for further investigation, but also helps researchers to avoid the generic claim that "very little is known" about a given topic, that is prevalent throughout much scientific literature. Finally, to identify the "known unknowns," working groups comprised of key stakeholders (e.g., researchers, fisheries managers, policy makers, etc.) can be effective platforms for identifying knowledge gaps and focusing research priorities. For example, the first meeting of the flapper skate working group in 2019, highlighted the ecology of juveniles and ontogenetic shifts in habitat use as key bottlenecks to effective management in European waters (Garbett et al., 2021).

1.3 | "*Who*" are we looking at?

The *who* question concerns up-to-date taxonomic resolution and the correct identification of the target species, two distinct considerations that can have a large bearing on data quality assurance—do the data correctly and unambiguously relate to the species in question? Skates and rays are subject to regular taxonomic revisions and continued misidentification, due to high morphological conservatism within the group and among juveniles (Cariani et al., 2017; Iglésias et al., 2010; Last et al., 2016; Serena et al., 2020). These issues can lead to errors in occurrence information, with knock-on effects for research outputs and management decisions (Beerkircher et al., 2009; Iglésias et al., 2010). Therefore, an integrated taxonomic approach incorporating both morphology and molecular tools is recommended to help minimize taxonomic inconsistencies (Rigby et al., 2019). For elasmobranchs, the NADH2 barcode has proven to be a robust marker for species discrimination (Naylor et al., 2012); the CO1 and Control Region barcodes have also seen some use in recent years (e.g., Bache-Jeffreys et al., 2021; Griffiths et al., 2010). This integrated taxonomic approach was central to resolving the taxonomy of the flapper skate, formerly known as the common skate (*Dipturus batis*). A seminal molecular study in 2010 revealed two genetically divergent and reproductively isolated clades within the "common skate" (Griffiths et al., 2010). After a century of taxonomic confusion (Garbett et al., 2023), the flapper skate and the common blue skate received formal recognition as species in 2021 (Ellis et al., 2021). This case exemplifies the importance of ensuring accurate species identification for conservation management, particularly in morphologically conserved species like skate, whose differing ecologies necessitate tailored management strategies.

1.4 | *Where* are they found?

Once the species has been resolved taxonomically, attention can shift to filling key knowledge gaps with respect to their distribution through data collection and research. This step may involve the identification of essential fish habitats (areas that are critical for species viability) such as foraging grounds or egg-laying sites (Heupel et al., 2007). Opportunistic data extracted from unrelated surveys can prove extremely valuable as a starting point; however, the vagaries, likely errors, and low taxonomic certainty of opportunistic data sets can result in a data-rich, information-poor (DRIP) scenario (Kosmala et al., 2016; Sulkava et al., 2007; Wilding et al., 2017). Beyond such discrepancies lies the issue of extractive sampling (e.g., fisheries surveys) which may inadvertently lead to increased mortality and habitat degradation (e.g., bottom trawling).

Moving forward, greater consideration should be given to non-destructive methods of distribution data collection. For example, Baited Remote Underwater Video systems (BRUVs) can be used to confirm a species' presence and provide information on abundances, habitat use, abiotic and biotic associations, and demographics (Benjamins, Dodd, et al., 2018; Whitmarsh et al., 2017). Additionally, this information can be combined into predictive habitat association models that can be extrapolated initially using environmental survey data (e.g., Kenny et al., 2003). For essential fish habitat surveys, ground truthing and higher resolution mapping (e.g., extent of egg laying sites) can be conducted using field-based methodologies such as divers, towed cameras, and remote operated vehicle transects (Dodd et al., 2022). This combined approach lays the foundation for long-term monitoring indicators that extend beyond the demographic information yielded by fisheries-dependent monitoring.

1.5 | *When* are they there?

Logically, many of the techniques used to establish distribution (i.e., *where?*) can address questions of seasonality and movement when repeated over time (e.g., groundfish surveys, angling records or baited remote underwater video deployments). However, repeated point sampling also comes with well-documented caveats (Lettink & Armstrong, 2003). For example, does the encounter of individuals at a given site in subsequent years suggest residency or a key habitat visited during a migratory cycle? A range of tracking techniques exists to help fill in the gaps, depending on the question being asked. For example, satellite telemetry is suitable for larger individuals and can provide continuous movement data for over a year (Farrugia et al., 2016; Wearmouth & Sims, 2009). When longer-term data are required to explore patterns of residency or dispersal (up to 10 years), acoustic telemetry can be an appropriate technique (Donaldson et al., 2014; Lavender et al., 2022; Neat et al., 2015). If used sequentially, these two approaches can complement each other, with exploratory satellite tracking data used to inform the design of acoustic arrays used for monitoring. When implemented, acoustic monitoring programs can underpin adaptive conservation strategies enacted in real time (e.g., Garcia, 1986; Hauzer et al., 2013; Rola et al., 2018).

2 | TOWARDS A CONSOLIDATED APPROACH TO DATA COLLECTION FOR FLAPPER SKATE AND OTHER LARGE BATOIDS

In recent years, our understanding of flapper skate ecology has advanced significantly through a series of geographically diverse studies addressing local conservation needs (e.g., Bache-Jeffreys et al., 2021; Dodd et al., 2022; Garbett et al., 2023; Régnier et al., 2024). Considerable efforts have come from Scotland, where the flapper skate is the only elasmobranch in Europe with dedicated marine protected areas for both adults and essential habitat (Dodd et al., 2022). However, given the skate's mobility and vulnerability, more protective measures enacted on a transboundary regional scale are needed to ensure long-term conservation success (Garbett et al., 2021, 2023).

To achieve this, standardized approaches to data acquisition throughout the species' range are critical. One of the key recommendations from the flapper skate working group (Garbett et al., 2021) is the adoption of consistent data collection methods to enhance research efficiency and ensure reproducibility. Collaborative platforms, such as working groups (e.g., Garbett et al., 2021; Harvey et al., 2021; McClure et al., 2023), play a crucial role in developing these standard approaches designed to deliver research outputs that inform policy (Kissling et al., 2018). Working groups also serve to establish and maintain collaborative relationships across regions, with digital infrastructures such as online repositories facilitating data sharing and backup between members (McClure et al., 2023).

This need for broader, coordinated action is reinforced by the wider context of ray species conservation. Research shows that 36% of rays (Subclass *Batoidea*) are threatened with extinction, and 12% are classified as data deficient, highlighting significant gaps in ecological knowledge (Dulvy et al., 2021). As with the flapper skate, these data gaps hinder effective conservation planning, underscoring the importance of improving data quality across species to inform recovery efforts (Siskey et al., 2019). In response to these challenges, this paper proposes a research framework for regional data collection, aimed at supporting the conservation of large batoids (Figure 1). By consolidating lessons learned from recent studies on skate and ray conservation, and applying standardized approaches to data collection, this framework offers a reproducible, iterative method that can be applied not only to the flapper skate but also to other wide-ranging, data-deficient species, helping to guide more effective conservation strategies.

ACKNOWLEDGMENTS

AG and JT were supported through the European Union's INTERREG VA Programme (Environment Theme) SeaMonitor project managed by the Special EU Programmes Body (SEUPB). Project ID IVA5060. SL is currently undertaking a PhD studentship funded by the Department of Agriculture, Environment and Rural Affairs and supported through the SeaMonitor project. This paper results from the Regional Flapper Skate Working group funded through the SeaMonitor project and the Irish Marine Institute.

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How to cite this article: Loca, S. L., Garbett, A., Houghton, J. D. R., Thorburn, J., Ó Cadhla, O., Clarke, M., Hannon, G., Pothanikat, L., Mayo, P. A., Gallagher, R., Hoppner, M. D. J., & Collins, P. C. (2025). A research toolbox for regional data collection to support the conservation of large batoids: A case study on the critically endangered flapper skate (*Dipturus intermedius*). *Conservation Science and Practice*, *7*(6), e70052. https://doi.org/10.1111/csp2.70052