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RESEARCH ARTICLE

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Reasons for unfulfilled breeding and transfer recommendations in zoos and aquariums

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Abstract

One of the primary tools for cooperatively managing animal populations within the Association of Zoos and Aquariums is through Breeding and Transfer Plan (BTP) recommendations. These recommendations consider population demographics, genetics, husbandry, and institutional needs and aim to improve population viability and long-term sustainability. However, fulfilling (i.e., completing) recommendations can be complicated by biological and logistical challenges. We examined institutional reasons for unfulfilled Breed With, Do Not Breed, Hold, and Send To recommendations collected in surveys in PMCTrack, software for tracking recommendation fulfillment, using descriptive and text-mining methods. Overall, 73 Animal Programs used PMCTrack to distribute 2335 surveys and accrued responses from 167 zoos and aquariums from 2007 to 2019, with a response rate of 56% (n = 1307). For Breed With recommendations, common reasons were related to an individual animal's status and a pair's breeding behavior; for all other recommendation types, reasons were often management or logistical factors. Most Breed With recommendations were attempted (≥55%) but did not result in detectable pregnancy/eggs or offspring, due to pair incompatibility or not enough time to successfully produce offspring. Hold and Do Not Breed recommendations were often unfulfilled because the BTP recommendation was replaced with an interim (i.e., updated) recommendation during the inter-planning period. Our results support the importance of some common population management practices, such as maintaining breeding pairs/groups for multiple BTPs to improve mate familiarity, examining husbandry mechanisms to promote breeding success, and making a concerted effort to adhere to planning timelines to facilitate transfers in alignment with breeding seasons.

KEYWORDS
Breeding and Transfer Plans, cooperative breeding program, PMCTrack, population management, Species Survival Plan

1 | INTRODUCTION

Over the last several decades, zoos and aquariums have shifted focus from primarily importing animals from the wild to managing ex situ populations through cooperative breeding; in the Association of Zoos and Aquariums (AZA), these programs are called Species Survival Plan® Programs (SSPs)(Association of Zoos and Aquariums, 2018; Powell et al., 2019). The goal of SSPs is to coordinate the management of animal populations among AZA-accredited zoos and aquariums to meet genetic and demographic targets, while considering husbandry, welfare, and institutional needs, with an ultimate goal of population health and long-term viability (Association of Zoos and Aquariums, 2018). One of the primary tools used in SSP management is Breeding and Transfer Plans (BTPs), which provide recommendations for each animal in a population for whether that individual should breed and/or be transferred in efforts to achieve population management goals. Under the current management framework, compliance with recommendations is mandatory for some populations (Green SSPs)—institutions are supposed to make every effort to complete them—while it is voluntary but strongly encouraged for others (Yellow and Red SSPs; Association of Zoos and Aquariums, 2018). However, despite increased attention to the health of zoo and aquarium populations, research has revealed that some ex situ populations are not achieving goals for long-term sustainability (Conway, 2011; Hibbard et al., 2011; Lees & Wilcken, 2009; Leus et al., 2011; Long et al., 2011), and lack of compliance with BTP recommendations has been suggested as a contributing factor to this trend (Lees & Wilcken, 2009).

A key component of effective management is assessing the outcomes of management actions and adapting actions to meet desired objectives (Holling, 1978; Walters, 1986; Williams, 2011). In this study, we focused on the assessment phase of population management in an effort to better understand outcomes of BTP recommendations ("management actions") and inform where management may be adapted. Overall, there are many potential reasons why a recommendation may be unfulfilled (i.e., fulfilled = compliant and completed as requested in the BTP, unfulfilled = noncompliant). Institutions participating in BTPs each have their own organizational mission and priorities, varying levels of space and resources, different levels of staff experience and areas of husbandry expertise, and diversity of animals in their care, all of which could potentially influence compliance with recommendations. Additionally, BTP recommendations are prescribed across >500 SSPs (Powell et al., 2019), including species that vastly differ in their biology, behavior, husbandry, and life histories. When recommendations are developed, consideration is given to species biology, well-being of the individual animal, benefit to the population, and an institutions' desires and resources. However, given the breadth of programs, institutions, and staff involved in BTP planning, there are a number of challenges that may arise after a recommendation is issued that impact the outcome of a recommendation. Therefore, while cooperative management remains a robust scientific process, the coordination, communication, and cooperation necessary to fulfill recommendations makes this practice both science and art (Traylor-Holzer, 2010).

Within a BTP, there are four primary types of recommendations: holding an individual at the current institution ("Hold"), sending an individual to a specified institution ("Send To"), breeding an individual with a specified mate or mates ("Breed With"), or preventing an individual from breeding ("Do Not Breed"). Previous research on BTP recommendations has revealed variability in fulfillment among SSPs, and fulfillment rates tend to be lower for recommendations that require action (i.e., Breed With [~20%] and Send To [~50%] vs. Do Not Breed [~96%] and Hold [~93%]) (Cronin et al., 2006; Faust et al., 2019). These previous studies explored whether a recommendation was fulfilled based on data available in studbooks, the electronic datasets for each population that includes each animal's life events (births, transfers, deaths) and parentage. However, more detailed reasons for why recommendations were unfulfilled and whether a recommendation was attempted require additional surveying of institutions. For example, a survey by Australasia's Zoo and Aquarium Association indicated inaction and communication within an institution as one of the leading causes a recommendation was unfulfilled (van Doorn, unpublished data; described in Lees & Wilcken, 2009). Additional contextual information such as this could prove beneficial during BTP planning; for example if behavioral challenges with introductions, courtship, or mating affected a previous Breed With recommendation, more thought might be given to re-issuing a recommendation to the same mating pair or group. More broadly across zoos and aquariums, it is important to understand whether the reasons for unfulfilled recommendations are primarily biological, which may be addressed with science and husbandry, or logistics and communication, which may be addressed with improved business processes, training, and other human-focused solutions.

In this study, we examined reasons for unfulfilled BTP recommendations using data collected in PMCTrack, an online database that serves as a record-keeping and monitoring tool for BTP recommendations (Faust et al., 2011a; 2011b). SSP Coordinators (also referred to as Program Leaders) can use PMCTrack to distribute Outcomes Surveys to institutions for each unfulfilled BTP recommendation to request additional context and reasoning on why a recommendation was unfulfilled. We analyzed the reasons and open-ended responses compiled in these surveys. We hypothesized that biological and husbandry-related factors would play a larger role in unfulfilled breeding recommendations (Breed With and Do Not Breed) while logistical and management considerations would be more likely to influence transfer recommendations (Send To and Hold), as fulfillment requires coordination among institutions and available space and resources. We also hypothesized that shorter inter-planning periods (i.e., the time allotted to complete a recommendation) would have a greater influence on Breed With and Send To recommendations, as these recommendations often require more time to implement and previous research found a correlation between inter-planning period length and fulfillment (Faust et al., 2019). In our analysis, we explored responses relative to the four main recommendation types (i.e., Breed With, Do Not Breed, Send

To, and Hold) and taxonomic classes (i.e., mammals, birds, and reptiles). We paired descriptive and text-mining methods to identify and further describe the primary factors influencing unfulfilled recommendations. A deeper understanding of why recommendations are unfulfilled will help increase recommendation fulfillment and secure long-term sustainability of ex situ animal populations. Though our analysis focuses on population management within AZA, our results may be applicable to other zoo and aquarium associations implementing similar population management systems.

2 | METHODS

2.1 | Population management and PMCTrack

Population management planning for AZA SSPs is typically conducted every 1–3 years, though this may be more or less frequent depending on population needs, species biology, and availability of population management services (Association of Zoos and Aquariums, 2018). Before planning, SSP Coordinators request all participating institutions communicate their wants and needs (e.g., desire to move out offspring, ability to breed an individual, lack of space to accommodate transfers), as these are given consideration during the planning process. During planning, a SSP Coordinator (who oversees management of a population) works with a Population Biologist (a scientific advisor skilled at the software tools and process of developing sound science-based recommendations) to develop a BTP that includes recommendations for each individual animal. Before a plan is finalized, it is distributed to participating institutions for comments and amendments. After a BTP is finalized, SSP Coordinators may issue interim recommendations, which are modifications to a recommendation to address changing circumstances (e.g., birth(s), behavioral issues) or to meet population and/or institutional needs (Association of Zoos and Aquariums, 2018). Interim recommendations are not officially published in a BTP but are negotiated between a SSP Coordinator and Institutional Representative.

PMCTrack was developed to record and evaluate the outcomes of BTP recommendations (Faust et al., 2011a, 2011b). PMCTrack evaluates each recommendation using events stored in a species' studbook (e.g., births, parentage, transfers between institutions) to determine if a recommendation was fulfilled before publication of the next BTP (See evaluation criteria in Table 1; Faust et al., 2019). This evaluation period between BTPs is referred to as the inter-planning period, which may vary by Program and over time. After evaluation of recommendation outcomes in PMCTrack is completed at the end of an inter-planning period, SSP Coordinators may choose to use Outcomes Surveys, which are sent to institutions for each animal with an unfulfilled recommendation in the last BTP. SSP Coordinators can choose to launch all four survey types (Breed With, Do Not Breed, Hold, Send To) or only a subset. Institutions will receive surveys for each part of an unfulfilled recommendation, so if an animal has an unfulfilled Breed With and an unfullfilled Hold recommendation, the institution will receive two surveys for that individual animal. In instances when a Send To recommendation is unfulfilled, surveys are sent to both the sending and receiving institution. For unfulfilled Breed With recommendations, surveys are only sent for the female to gather information on the breeding pair. Surveys are distributed when an SSP is beginning to prepare the next BTP, so that survey results may inform the next set of recommendations. All survey responses in this analysis were compiled and stored in PMCTrack. PMCTrack's original design was approved by Lincoln Park Zoo's Research Committee in 2008. All surveys are sent to Institutional Representatives to be filled out on behalf of (i.e. speaking for) their institution. As such, they are not covered under Institutional Review Board (IRB) processes focused on human subjects, based on consultation and review with Lincoln Park Zoo's IRB.

2.2 | Outcomes survey description

In efforts to better understand the outcomes of BTP recommendations, Outcomes Surveys were designed to gather additional information on why a recommendation was unfulfilled. Outcomes Surveys provide the reason a recommendation was scored as unfulfilled (e.g., for a Breed With recommendation, “no offspring produced” or “offspring produced with unrecommended mate”), and then requests that the user provides a primary (mandatory) and secondary (optional) reason the recommendation was unfulfilled. Each of the four recommendation types have a different subset of potential reasons; when aggregated, these result in 111 reasons in

TABLE 1 Evaluation criteria for scoring recommendations in PMCTrack (adapted from Faust et al., 2019)

Recommendation type	Outcome[a]	
	Fulfilled	Unfulfilled
Breed With	At least one offspring produced with recommended mate	No offspring produced with recommended mate or offspring produced with unrecommended mate
Do Not Breed	No offspring produced	Any offspring produced
Send To	Transferred to recommended institution	Not transferred or transferred to unrecommended institution
Hold	Held at starting institution	Any transfer event

[a]For an outcome to be scored fulfilled or unfulfilled, each recommendation is evaluated against events recorded in the studbook before the next Breeding and Transfer Plan.

7 categories, which provided the raw data for coding and analyses. In addition to these predefined reasons, participants may provide an optional open-ended response for further context and description. See Supporting Information for an example of an Outcomes Survey.

2.3 | Data coding, preparation, and analysis

Outcomes Survey data were downloaded from PMCTrack on May 21st, 2020. For analysis, we adapted the methods described by Saldaña (2015) to prepare our final dataset using first and second coding cycles. Protocol coding, or use of PMCTrack's pre-established coding system for Outcome Surveys, was used in the first cycle. Initial examination of responses revealed a high prevalence of "OTHER—see notes" as the primary reason a recommendation was unfulfilled. However, the submitted open-ended responses often described a primary reason already listed in the survey instrument. We used qualitative coding methods to identify patterns in open-ended responses to potentially recode responses (Saldaña, 2015). To do this, we had three individuals independently review all open-ended responses and, when supported, recode with an appropriate primary reason. If two or more reviewers recoded the same primary reason, that response was retained. For instances where all reviewers disagreed, each case was discussed as a group until a primary reason code was agreed upon, if applicable. Approximately 90% of "OTHER—see notes" responses had sufficient information to be re-categorized.

In the second coding cycle, we evaluated the existing codes with the purpose of grouping reason codes into existing categories, generating new categories, and collapsing reason codes that were infrequently used. When combining reasons, we ensured reason descriptions were similar and revised subsequent descriptions to capture this change. This second coding cycle resulted in 93 primary reasons (Table S1) in 8 categories (Table 2); we developed an additional category of "BEHAV" for reasons where animal behavior prevented a recommendation from being fulfilled. This resultant dataset from the second coding cycle was used in our final analysis. For Breed With recommendations, we also examined whether breeding was attempted, as fulfillment of these recommendations are crucial to successful population management. We categorized each unfulfilled Breed With recommendation as attempted if the reason description or text comments listed evidence of breeding behavior or that animals were introduced, unattempted if the recommendation was affected by communication or logistics such that animals were never introduced, and unclear if this could not be deciphered.

We were also interested in the relationship between inter-planning period and reasons for unfulfilled recommendations. We first used a Kruskal-Wallis test (Kruskal & Wallis, 1952) to determine whether inter-planning period differed among primary reasons for unfulfilled recommendations. A significant Kruskal–Wallis test justified use of Dunn's multiple comparisons test using the Holm adjustment (Holm, 1979), which accounts for unequal sample sizes (Dunn, 1964), to differentiate reason types by inter-planning period length. Additionally, we were interested in how the distribution of surveys and response rates varied by SSP management designation (i.e., Population Management Plan [PMP], Red SSP, Yellow SSP, Green SSP; Association of Zoos and Aquariums, 2018), as these designations describe the status of a population and have different expectations of compliance and participation. Animal Programs are assigned a management designation by AZA based on their genetic

TABLE 2 Reason categories and descriptions for unfulfilled Breeding and Transfer Plan recommendations in Outcomes Surveys administered between 2007 and 2019

Category	Description
ANIM	Reasons related to the status and health of the individual animal. This includes items related to illness, physical condition, and whether an animal died.
BEHAV	Reasons related to an individual animals' behavior or breeding pair/group. This includes behavioral incompatibility, lack of breeding behavior, or behavioral issues necessitating or preventing transfer.
BREED	Reasons related to breeding. This includes pregnancy complications and unsuccessful rearing of eggs. Only relevant to Breed With recommendations.
COM	Reasons related to communication. This includes lack of communication between SSP Coordinators/Institutional Representatives, inability to communicate wants and needs, not receiving a final BTP or staff being unaware of a recommendation.
INST	Reasons related to the institution. This includes changes to an institutions' wants and needs or changes to a recommendation due to other cancelled/pending recommendations.
MGMT	Reasons related to management. This includes items related to data management (e.g., wrong ID or sex in studbook), animal husbandry, reproductive management, and whether an interim recommendation had been issued.
OTHER	Reasons related to other circumstances. This includes open-ended explanations, unknown reasons, incorrect evaluation, or whether a transfer was in progress (Send To recommendations only).
SHIP	Reasons related to shipment for transfer recommendations. This includes items related to permits, veterinary exams, finances, weather, health, and exhibits. Only relevant to Send To recommendations.

Abbreviation: BTP, Breeding and Transfer Plan.

diversity and population size (Association of Zoos and Aquariums, 2018). Under the current designation, Green SSPs are considered the most viable (i.e., >90% gene diversity in 100 years and >50 individuals) and participation in population management is required—institutions are expected to at least attempt to complete recommendations in the BTP (Association of Zoos and Aquariums, 2018). Yellow and Red SSPs are projected to retain <90% gene diversity in 100 years with Red SSPs having <50 individuals, and participation in population management is voluntary but strongly encouraged (Association of Zoos and Aquariums, 2018). Early surveys in the sample were also sent by programs with historical designations (i.e., not color-coded) of SSP and PMPs; these SSPs still had expectations of mandatory compliance, while PMPs were voluntary. We also stratified our analyses by the three most common taxonomic groups in our dataset (i.e., mammals, birds, and reptiles), as we anticipated that reasons for unfulfilled recommendations may vary given differences in biology, husbandry, and management.

Survey respondents could provide both a primary and secondary reason for a single unfulfilled recommendation. Here, we explicitly refer to "primary reasons" and "secondary reasons" when we left these reasons separate in an analysis, or the more general "reasons" in instances when we pooled reasons for descriptive purposes. Additionally, given that survey responses were sent to both sending and receiving institutions for an unfulfilled Send To recommendation, we focused on surveys acquired from the sending institution so that each recommendation had a single response. However, in instances when a sending institution did not respond to a survey, we used the response from the receiving institution in its place.

2.4 | Text mining

We further analyzed all open-ended survey responses to look for additional patterns using text mining procedures and visualization from the "tidytext" package in R (Silge & Robinson, 2016). We first used tokenization, which parses out individual words to serve as tokens using spaces and punctuation as delimiters (Miner et al., 2012). During this process, stop words that were uninformative (e.g., "the", "to", "that") were removed, as this reduces computing time and can increase the accuracy of text mining tasks (Feldman & Sanger, 2007; Weiss et al., 2015). We also stemmed (i.e., removing inflections to reduce words to their stem) and lemmatized (i.e., grouping inflected words and variants) all words to ensure that similar words and their derivations were analyzed together. However, for ease of communication we refer to all words in text and figures using their base form (e.g., recommends, recommended, recommendation = recommend).

In our final step of preprocessing, responses were mined and analyzed to find common word pairings that appeared consecutively (i.e., bigrams), as these pairs could provide valuable context as to why a recommendation was unfulfilled. We tabulated counts for each word pair and extracted those that frequently occurred within each recommendation type and taxonomic class (i.e., mammals, birds, and reptiles). However, we were also interested in the context in which word pairs were used. To examine this, we conducted a sentiment analysis where we calculated a sentiment score for each open-ended response using the number of words that carried positive or negative sentiment. We used the Bing Liu lexicon (Hu & Liu, 2004) to attach sentiment to words where a 1 was given for a word with positive sentiment and −1 was given for a word with negative sentiment. We summed these sentiments to achieve an overall sentiment score for every open-ended response, where values equal to 0 were neutral, >0 were positive, and <0 were negative. We used R (R Core Team, 2019) for all data analyses and text mining.

3 | RESULTS

As of May 2020, 73 Programs (out of 484 possible as of 2021; AZA, personal communication, June 1, 2021) had used PMCTrack to distribute 2335 Outcomes Surveys and accrued responses from 167 zoos and aquariums that participated in population management planning from 2007 to 2019 (Tables 3 and 4). Of responding institutions, most were AZA-accredited, though we also received responses from 14 institutions outside of AZA (i.e., not accredited or international facilities). For Animal Programs using Outcomes Surveys, 25 used surveys for more than one BTP. A majority of our sample was from mammal Programs and Programs with a Yellow SSP designation; surveys about unfulfilled Breed With recommendations were the most frequently used survey type across all taxonomic classes (Table 4 and Table S2). The survey response rate was 56% overall ($n = 1307$), but rates varied annually (range: 33.33%–70.21%; Table S3) without a directional trend and among recommendation types and taxonomic classes (Table 4). Of completed surveys, 25% included both a primary and secondary reason ($n = 595$) and 58% included an open-ended response providing additional explanation on why a recommendation was unfulfilled. Additionally, the response rate was relatively similar across Red (61%; $n = 79$), Yellow (54%; $n = 856$), and Green (58%; $n = 339$) SSP designations.

The most common reasons for unfulfilled Breed With recommendations were in the "ANIM", "BREED", and "BEHAV" categories (Table 2 and Figure 1). For Do Not Breed, the "MGMT" and "OTHER" categories were most common in both mammals and birds, followed by "ANIM" for mammals and the "INST" category for birds (Figure 1). Responses were relatively evenly distributed among reason categories for unfulfilled Send To recommendations, though the "INST" and "OTHER" categories were reported frequently for mammals while "OTHER" and "COM" were relatively common for birds and reptiles (Figure 1). "MGMT", "INST" and "OTHER" reason categories were most common for unfulfilled Hold recommendations, with "OTHER" being the most prominent for reptile Programs (Figure 1).

Examination of reasons for unfulfilled recommendations across and within taxonomic groups revealed that a majority of Breed With recommendations were unfulfilled due to the animal's physical status and breeding behavior (Figures 2 and 3). Overall, the most common reasons for unfulfilled Breed With recommendations were "no

TABLE 3 Number of programs, institutions that completed surveys, mean inter-planning period, and range in final Breeding and Transfer Plan dates stratified by taxonomic class and recommendation type for programs participating in Outcomes Surveys between 2007 and 2019

Taxon	Type	No. programs	No. institutions	Mean inter-planning period (*SE*)[a]	Range in final plan dates
Mammals	Breed With	38	132	2.12 (0.05)	2010–2019
	Send To	26	55	2.37 (0.11)	2010–2019
	Hold	27	57	2.74 (0.09)	2010–2018
	Do Not Breed	21	37	3.03 (0.17)	2011–2018
Birds	Breed With	24	77	2.96 (0.09)	2007–2019
	Send To	16	38	2.63 (0.19)	2009–2019
	Hold	19	27	3.56 (0.22)	2007–2017
	Do Not Breed	9	17	4.45 (0.37)	2009–2019
Reptiles	Breed With	12	32	2.88 (0.18)	2012–2016
	Send To	7	11	3.25 (0.21)	2012–2016
	Hold	3	10	4.45 (0.13)	2012–2016
	Do Not Breed	1	4	5.01 (–)	2015
	Total	73[b]	167[b]	2.63 (0.04)	2007–2019

[a]Units are in years and *SE* = standard error.

[b]Totals represent number of unique programs and institutions in our sample.

TABLE 4 Number of Outcomes Surveys sent, primary reasons, secondary reasons, open-ended responses, and response rates by recommendation type from programs participating in Outcomes Surveys between 2007 and 2019

Taxon	Type	No. surveys sent	Response rate (%)	No. primary reason responses	No. secondary reason responses	No. of open-ended responses
Mammals	Breed With	840	62.74	527	257	306
	Send To	227	51.98	118	60	78
	Hold	246	50.81	125	45	66
	Do Not Breed	106	55.66	59	20	35
Birds	Breed With	342	60.53	207	97	108
	Send To	138	44.20	61	24	31
	Hold	105	51.43	54	23	36
	Do Not Breed	69	43.48	30	12	25
Reptiles	Breed With	148	46.62	69	37	40
	Send To	61	50.82	31	11	14
	Hold	37	56.75	21	7	14
	Do Not Breed	16	31.25	5	2	5
	Total	2,335	55.97	1,307	595	758

pregnancy/eggs" observed in mammals, indicating that the pair were placed together for breeding, breeding behavior was observed, but there were no signs of pregnancy/eggs. For birds and reptiles, animal death (of either animal in the pair) and behavioral issues with a pair were prominent reasons for unfulfilled Breed With recommendations (Figures 2 and 3). Contrastingly, reasons for unfulfilled recommendations for all other recommendation types were mostly related to management, institutions, and other (Figure 2). For unfulfilled Do Not Breed recommendations, mammal Programs frequently reported interim recommendations being issued and staff being unable to prevent breeding, while bird Programs also cited difficulty preventing breeding as well as changes to an institutions'

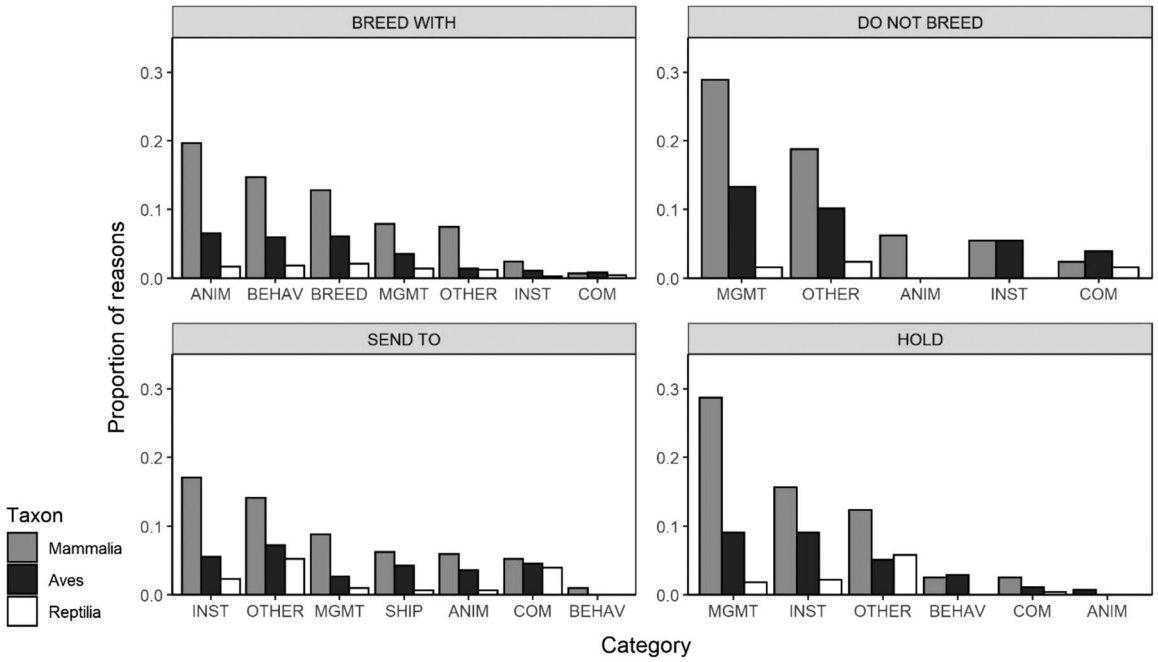

FIGURE 1 Proportion of reason responses (primary and secondary) per category for unfulfilled Breeding and Transfer Plan recommendations for each recommendation type and taxonomic class from 2007 to 2019. See Table 2 for description of reason categories

wants and needs. (Figure 3). Unfulfilled Do Not Breed recommendations for reptile programs listed inaccurate outcomes (i.e., when a respondent disagreed that a recommendation was unfulfilled), and issues with communication ("no draft/final plan received"), though we caution that this finding was based on a small sample of reptile surveys (Figure 3 and Table 4). For birds and mammals, changes to an institutions' wants and needs were the most common reasons for both unfulfilled Hold and Send To recommendations; additionally, interim recommendations were a common reason for unfulfilled Hold recommendations (Figure 3). For reptiles, "unknown" was the most common response for unfulfilled Hold recommendations while "see notes", "inaccurate outcome", and "no communication" were the top reasons for unfulfilled Send To recommendations (Figure 3).

Given that interim recommendations are not officially recorded, PMCTrack scores the original recommendation issued in the BTP as unfulfilled. Therefore, we were interested in the potential influence of interim recommendations on fulfillment. Overall, we found ~10% (primary = 152, secondary = 32) of all reasons identified an interim recommendation that influenced fulfillment of the original recommendation. Interim recommendations were most frequently indicated as a reason for unfulfilled Hold ($n = 106$), followed by Send To ($n = 29$), Do Not Breed ($n = 25$), and Breed With recommendations ($n = 24$; Table S1).

Our Kruskal–Wallis test for differences in inter-planning period length among top primary reasons was significant ($\chi^2 = 166.43$, $df = 13p$, = <.01), justifying a multiple comparisons test. We found differences in inter-planning period length between primary reason responses for Breed With, Send To, and Hold recommendations (Figure 4). Reporting death of an animal occurred more frequently with slightly longer inter-planning periods, while responses suggesting that breeding occurred but did not result in evidence of pregnancy or eggs correlated with shorter inter-planning periods (Figure 4). For both Send To and Hold recommendations, "OTHER—unknown" responses occurred more often in Programs with longer inter-planning periods (-Figure 4). We did not find significant differences in inter-planning period length for reasons for unfulfilled Do Not Breed recommendations.

For Breed With recommendations, it was also possible to group survey responses based on whether they were attempted but unsuccessful or unattempted. Of the 803 unfulfilled Breed With surveys that received a response, breeding was attempted in at least 55% ($n = 444$) of cases based on the survey's primary reason. Top primary reasons for attempted Breed With recommendations were "no pregnancy/eggs" ($n = 147$), "no copulation" ($n = 97$), and "no courtship" ($n = 59$). Another 22% ($n = 176$) of unfulfilled Breed With recommendations were unattempted, mostly due to the physical status of the animal (i.e., non-reproductive), although whether the animal was in that physical state the entire inter-planning period or whether a recommendation was attempted before a status change is unknown. Most common primary reasons for unattempted Breed With recommendations were that the animal was "non-reproductive" ($n = 66$), "mate was not transferred" ($n = 30$), or changes to an institution's wants and needs (i.e., "W/N changed"; $n = 16$). In ~23% ($n = 183$) of primary reasons it was unclear whether breeding was attempted.

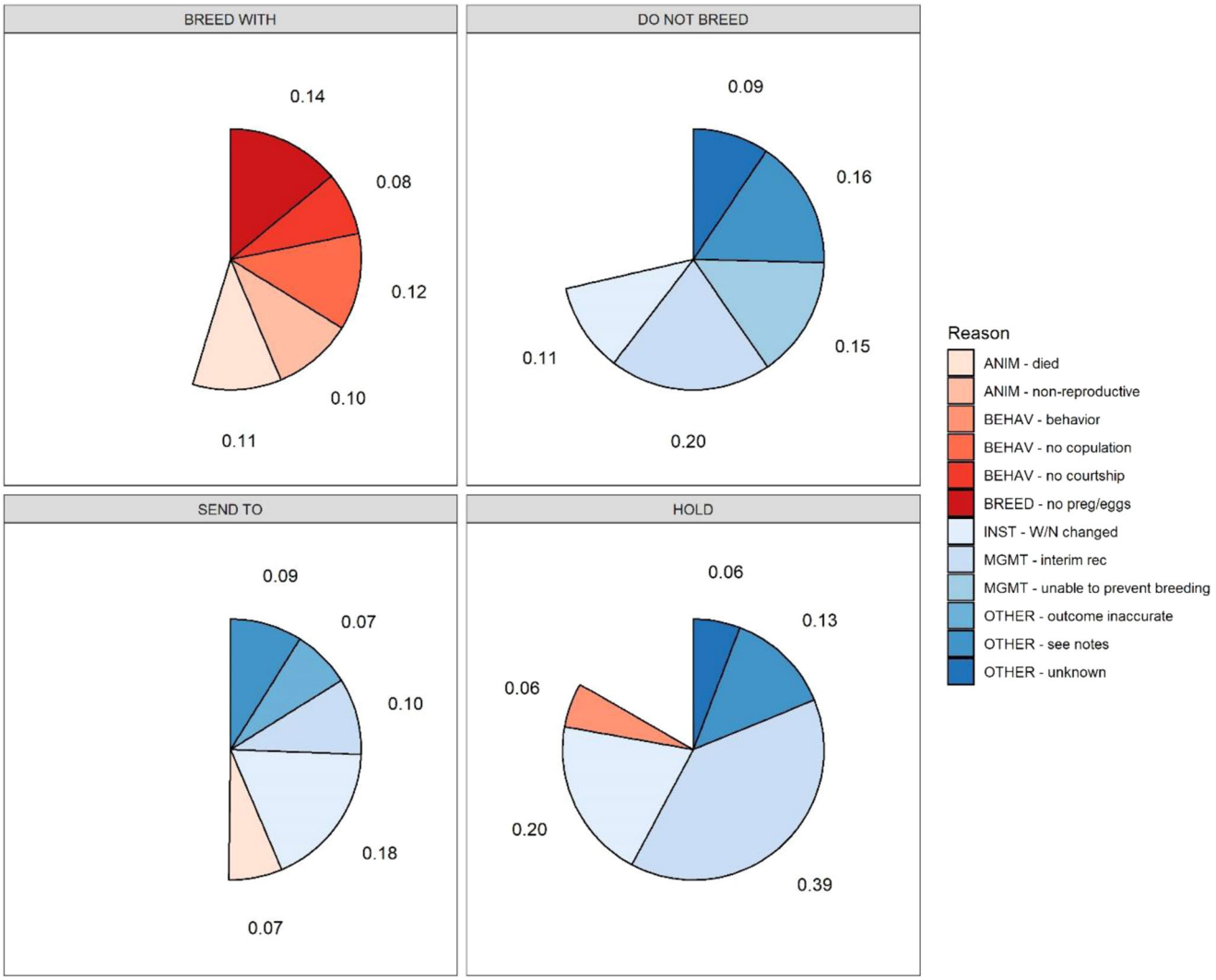

FIGURE 2 Proportion of top five reason responses (primary and secondary) for unfulfilled Breeding and Transfer Plan recommendations within each recommendation type from 2007 to 2019 for all taxa. Reason totals for calculating proportions: 1194 (Breed With), 128 (Do Not Breed), 305 (Send To), 275 (Hold). See Table S1 for description of reason categories

Assessment of open-ended responses using word pairs provided further insight into reasons recommendations were unfulfilled. Reference to breeding season and behavior were commonly listed items for unfulfilled Breed With recommendations, though egg laying and observed breeding were also frequently noted (Figure 5). Breed season and behavior were used in neutral and slightly positive contexts, potentially indicating optimism for breeding in the future, while egg laying and observed breeding were used in slightly negative contexts (Figure S1). The majority of frequent word pairs for Do Not Breed were from bird Programs, with many referring to program leadership or SSP recommendations, potentially indicative of an interim recommendation (i.e., breed recommend, program leader, SSP recommend), or managing eggs to prevent offspring (i.e., egg replace, keeper pull, dummy egg; Figure 5), all of which were used in positive contexts (Figure S1). For both Send To and Hold recommendations, most word pairs referred to Program leadership and interim recommendations (i.e., program leader, SSP recommend, recommend transfer), though Hold word pairs were primarily from reptile Programs indicating turnover in department staff contributing to unfulfilled recommendations (Figure 5). However, we acknowledge that this finding for reptiles was from a relatively small sample of open-ended responses ($n = 14$). Sentiment for word pairs found for Send To and Hold recommendations were primarily positive or neutral aside from "receive institution", which was used in negative contexts for unfulfilled Send To recommendations (Figure S1). Overall, sentiment for the top word pairs in open-ended responses was often positive or neutral, with fewer instances of word pairs with negative sentiment, which were only found for action recommendations (i.e., Breed With and Send To; Figure S1).

4 | DISCUSSION

Our analysis of the reasons provided in Outcomes Surveys for unfulfilled BTP recommendations is the first systematic understanding across SSPs as to why some recommendations do not occur as

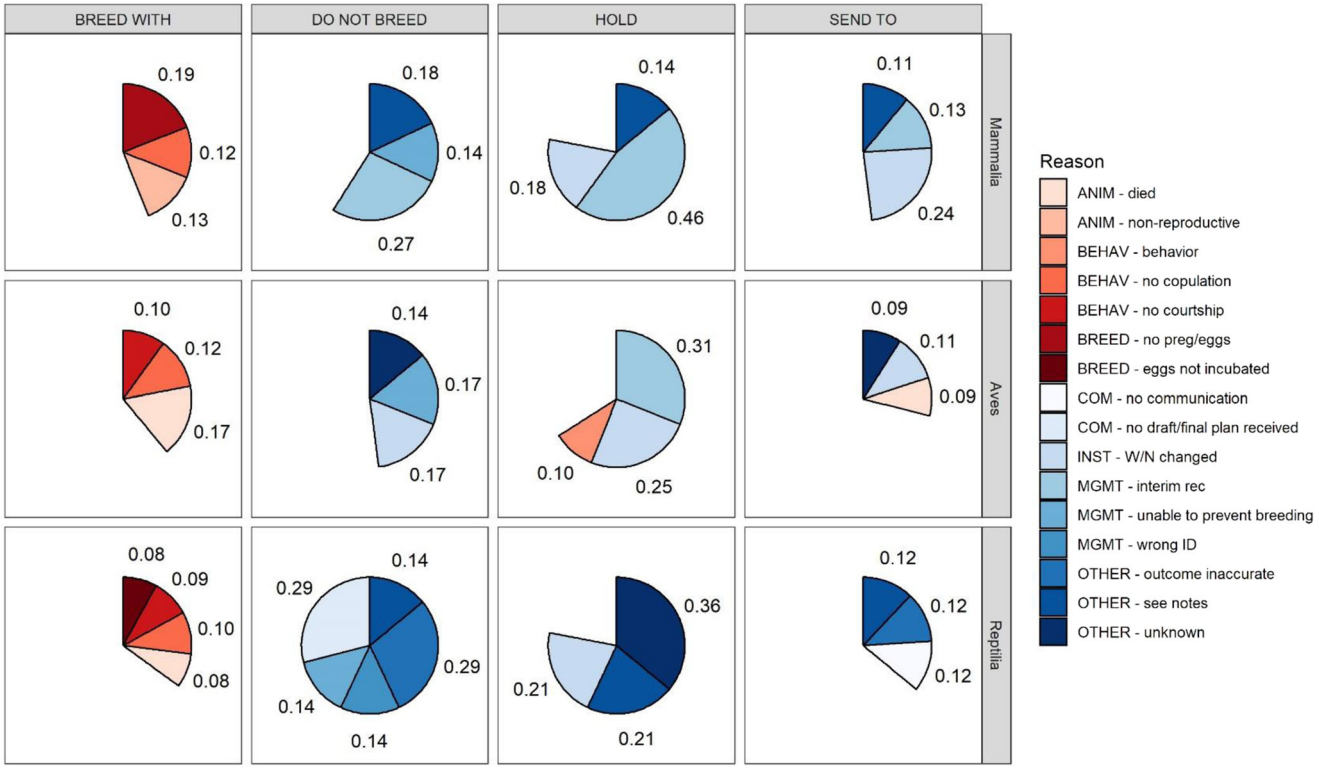

FIGURE 3 Proportion of top three reason responses (primary and secondary) for unfulfilled Breeding and Transfer Plan recommendations within each recommendation type and taxonomic class from 2007 to 2019. See Table 4 for reason totals used in calculating proportions and Table S1 for description of reason categories and associated sample sizes

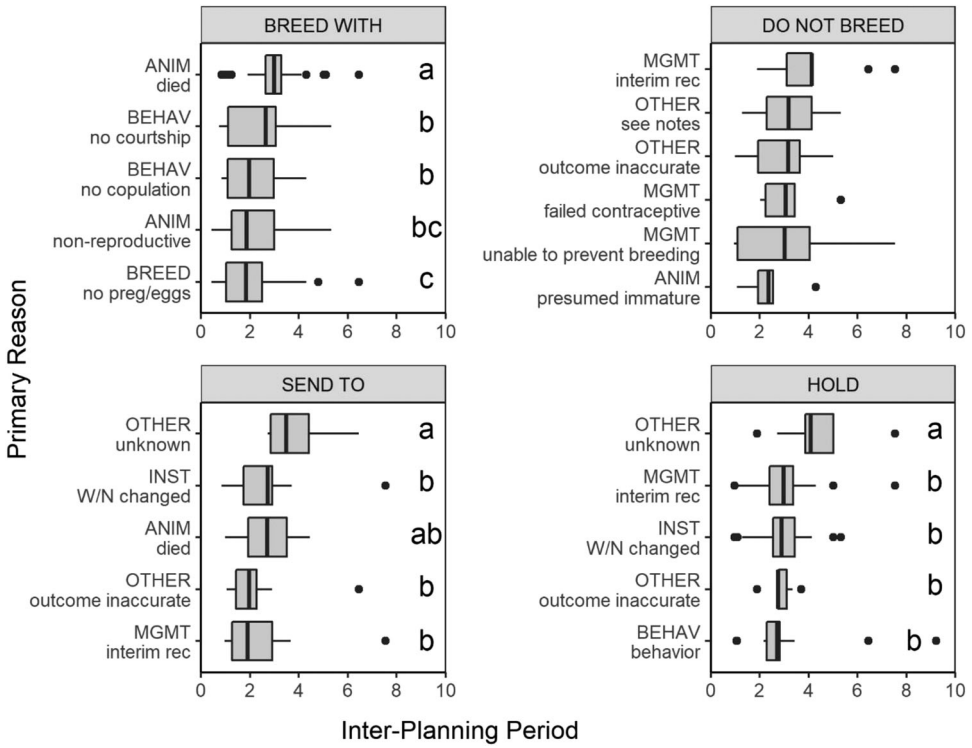

FIGURE 4 Top five primary reasons for unfulfilled Breeding and Transfer Plan recommendations by inter-planning period (years) and recommendation type from 2007 to 2019. Vertical lines within boxes represent the median and points are outliers. Letters represent groupings from Dunn's multiple comparison test (Dunn, 1964) indicating significant differences in inter-planning period length among groups

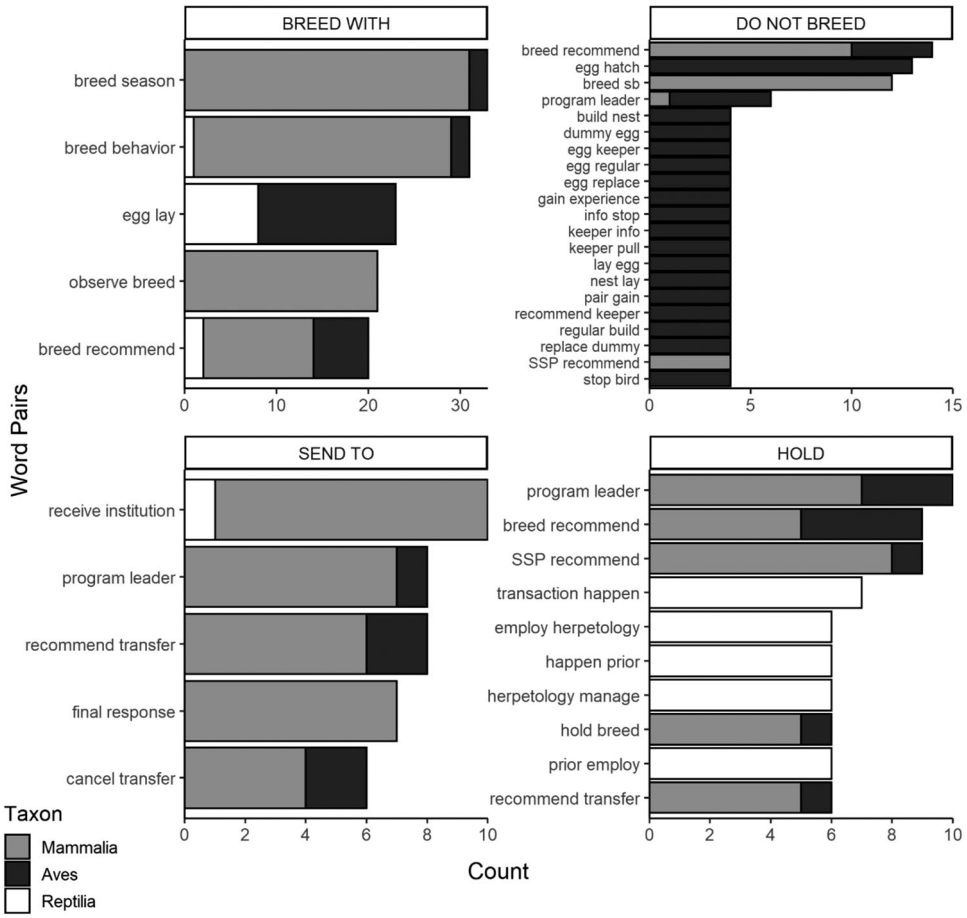

FIGURE 5 Top five word pairs (including ties) from open-ended responses for unfulfilled Breeding and Transfer Plan recommendations by taxonomic class and recommendation type from 2007 to 2019

requested. For Breed With recommendations, arguably one of the most critical recommendation types for an SSP's success, we found that at least 55% of recommendations were being attempted (i.e., the animals were being introduced for breeding) and that biological reasons, more often than logistical or communication issues, result in unfulfilled recommendations. Based on this subset of SSPs, the challenges in carrying out breeding recommendations tend to be related to the individual animal's status, and/or a breeding group or pair's behavior and husbandry. Continued and taxon-specific research on methods for improving breeding success may be needed to increase Breed With fulfillment rates, but it is encouraging that the AZA community is attempting these recommendations. To gain a better understanding of how frequently institutions are attempting all recommendation types, rather than a post hoc analysis of Breed With recommendations, programming modifications to PMCTrack's Outcomes Surveys will soon allow institutions to more directly indicate whether they attempted a recommendation or not. This should give the AZA community a more robust view of recommendation "compliance," which reflects both fulfilling and attempting recommendations.

All other recommendation types tended to be affected by institutional preferences and management as well as interim recommendations. Therefore, lack of fulfillment in these recommendation types was often to meet other logistical or management needs after a BTP was finalized. It also appears that when a recommendation is not feasible, institutions are actively seeking interim recommendations from SSP Coordinators, which is valuable in ensuring Programs achieve demographic and genetic goals. Similar to another recent study on population management (Che-Castaldo et al., 2021), our findings provide a positive outlook on commitment by the zoo and aquarium community in cooperatively managing ex situ populations.

Reasons for unfulfilled Breed With recommendations differed slightly by taxonomic class. Mammal Programs primarily reported that animals were breeding but did not result in offspring or any evidence of pregnancy (i.e., "BREED—no preg/eggs"). This may be related to the inter-planning period length (i.e., time allotted for breeding before a recommendation is evaluated) as higher fulfillment of breeding recommendations has been shown in Programs with longer inter-planning periods (Faust et al., 2019) and we observed a correlation between "no pregnancy/eggs" responses and shorter inter-planning periods in this study. Difficulty completing breeding recommendations within this timeframe was further supported in open-ended responses, where time and complications with seasonal

or cyclical breeding species were indicated. These findings align with previous research conducted on breeding success in select species of ex situ mammals, which identified higher success in mates who have been paired longer and have greater familiarity with one another (Casimir et al., 2007; Fisher et al., 2003; Martin & Shepherdson, 2012). Additionally, optimally timing breeding attempts may also be challenged by irregularity in reproductive cycling in some individuals/species (e.g., acyclicity unrelated to season, erratic cycle length), potentially driven by body condition, postbirth anestrus, or other social and environmental cues in ex situ environments (Brown et al., 2001; Edwards et al., 2015; Kersey et al., 2010; Morfeld & Brown, 2016). In addition to these timing-related factors, other post-breeding factors possibly influencing pregnancy in mammals include aspects of husbandry, breeding experience, stress, reproductive physiology, and reproductive status, among others (Saunders et al., 2014; Taylor & Poole, 1998; Zhang et al., 2004). Contrastingly, Breed With recommendations for bird and reptile Programs were more often impacted before breeding, mainly due to an animal or its mate dying or mate pairs not exhibiting breeding behaviors (i.e., courtship and copulation). Lack of breeding behaviors may lend support to breeding strategies that incorporate mate choice, as this management tactic is gaining attention in ex situ breeding programs to promote pair-bonding and breeding success (Greggor et al., 2018; Ihle et al., 2015; Martin-Wintle et al., 2019). Additionally, breeding with preferred mates has been linked to greater reproductive output and early survival of offspring in ex situ birds (Bluhm & Gowaty, 2004; Klint & Enquist, 1981). For reptiles, knowledge of the role of mate choice in ex situ breeding is limited, but in situ research has shown preferences for behavioral displays/advertisement, body size, and coloration (Baird et al., 2007; Belliure et al., 2018; Dubey et al., 2009; Galeotti et al., 2005; Tokarz, 1995). Additionally, factors related to animal husbandry may also be influencing ex situ breeding behaviors in some reptile species, though knowledge of husbandry factors influencing breeding is varied and causes of reproductive failure can be difficult to diagnose (Croyle et al., 2016; Horn & Visser, 1997; Shanbhag, 2002). Breeding behavior in reptiles has been linked to aspects of an animal's physiology, environmental stimuli (e.g., light and temperature), and social cues (Horn & Visser, 1997; Whittier & Tokarz, 1992), many of which can be addressed via husbandry. Across all taxa, these surveys lend support to the idea that continued research into the diverse factors impacting breeding success as well as investment in training and developing breeding husbandry skills will be important to increasing Breed With fulfillment.

For Do Not Breed, Hold, and Send To recommendations, we observed a high frequency of instances where interim recommendations were requested and/or issued. Fulfillment rates for Do Not Breed, Hold, and Send To recommendations have previously been shown to be ~90% or higher for Do Not Breed and Hold and ~60% for Send To (Faust et al., 2019; Gray, Faust, Senner, Schad Eebes, & Che-Castaldo), and our results indicate that these rates would increase if interim recommendations are accounted for. The prevalence of interim recommendations in our sample could indicate a need for more frequent BTP planning to account for changing wants and needs, which may be increasingly necessary for species with shorter life histories. Another potential explanation for frequent interim recommendations is that the wants and needs of institutions are not being communicated to the SSP or successfully accounted for in the population management process, though respondents could have explicitly indicated the latter in Outcomes Surveys (i.e., "COM—W/N not addressed"). However, during population management planning, SSP Coordinators and Population Biologists make a concerted effort to honor the requests of each institution to the best of their abilities. Therefore, it is more likely that the patterns here simply reflect the stochasticity of population management and shifting wants and needs, where unexpected scenarios arise that require adaptability to accommodate both the institution and Program. For this reason, interim recommendations appear to be serving their purpose and continue to be an important tool for SSP Coordinators and institutions. Future detailed record-keeping and scoring of interim recommendations could add further value and insight into BTP recommendation compliance, and programming modifications to PMCTrack will soon be available to support this.

For our sentiment analysis of open-ended responses, common word pairs were frequently used in positive or neutral contexts across recommendation types. This result may indicate commitment to meeting population management objectives and optimism for completion of a recommendation in the future. For example, several responses referencing breeding season identified continued effort toward completing the recommendation (i.e., "We will continue to try, especially once breeding season starts again" and "The pair is compatible together so we are hoping for a better outcome next breeding season"). However, it is worth noting that surveys used in our analysis were self-reported and, given that surveys are distributed for unfulfilled recommendations, responses may exhibit social desirability bias (i.e., responses adjusted to be socially acceptable or viewed more favorably) to frame noncompliance in a positive context (Beretvas et al., 2002; Gonyea, 2005). Thus, we caution that the positive sentiment we observed in open-ended responses may reflect this bias.

An important caveat is that we pooled primary and secondary reasons when we report proportions of reasons observed in this study. In these cases, two reasons are reported for a single unfulfilled recommendation, meaning that some recommendations will have a larger impact on resultant proportions if both a primary and secondary reason were selected (primary and secondary reasons were selected in 25% of surveys). Nonetheless, our objective was to describe the overall reason a recommendation was unfulfilled. Therefore, we believed that incorporation of both primary and secondary reasons provided the most complete explanation for why a recommendation did not occur. Additionally, our analysis is derived from a sample of 73 Programs (~15% of all SSPs) that chose to use Outcomes Surveys and the 167 institutions (~55% of all current AZA accredited and partner institutions) that chose to respond to survey requests (AZA, personal communication, November 24, 2020). Additionally, though SSP Programs exist for amphibians, fishes, and invertebrates, we were unable to examine these groups as they did not

participate in Outcomes Surveys within the analysis period. We also acknowledge that responses for mammal Programs comprised a majority of our sample, but this taxonomic bias is reflected across all AZA Programs (i.e., ~42% of SSPs are mammals, AZA, personal communication, June 1, 2021). In addition, Breed With responses comprised a majority of the sample, but this is not unexpected given that Breed With recommendations tend to have the lowest fulfillment rate (~20%) and would thus generate a larger number of surveys; in addition, these are the responses that SSP Coordinators are most interested in, so they may preferentially launch Breed With surveys and not other survey types. We encourage continued and broader use of Outcomes Surveys by a greater diversity of SSPs to help improve our understanding of recommendation noncompliance and efficacy of population management. Although the focus of this study was primarily on BTP recommendations in AZA Animal Programs, we believe our results are broadly applicable to other zoological associations. We provide taxon-specific results and suggestions that are pertinent and generalizable to many commonly held species occurring in a variety of zoos and aquariums worldwide. Furthermore, population management systems similar to AZA (i.e., using breeding and transfer recommendations) exist in multiple regional associations around the world, and therefore, reasons for unfulfilled recommendations may be consistent across associations.

Our analysis of Outcomes Surveys revealed that in most cases individuals implementing BTP recommendations are making efforts to do so or seeking guidance from program leadership if unable to complete a recommendation as prescribed. This highlights strong investment in ex situ population management practices by the zoo and aquarium community, which will aid in achieving long-term population sustainability. In terms of population management, responses to Outcomes Surveys revealed several items for consideration during future planning. First, breeding recommendations for mammals should span multiple BTPs if positive signs of breeding behavior occurred, even if unsuccessful in the first interplanning period, as increased familiarity with mates could improve breeding success. This may currently happen if the SSP Coordinators and Population Biologists receive input that the institution is committed to carrying out the recommendation and the recommendation is still beneficial for the population. Outcomes surveys can give more evidence on whether this is a good strategy for an SSP. However, repeated instances across multiple BTPs of observed breeding without pregnancy should prompt thorough reproductive evaluations (e.g., physical exams, hormone analyses) or adjustments to mate pairings. Second, Programs for seasonal or cyclical breeding species should strongly consider timing of BTP planning so that transfer and breeding recommendations can be acted on in time for the breeding season, as failure to do so could result in loss of a season and limits time for animals to successfully reproduce. In most cases the timing of BTP planning is arranged to account for this, but our results underscore the importance of this timing to fulfill breeding recommendations. Third, difficulty inducing appropriate breeding behaviors in bird, and potentially reptile Programs, may encourage Programs and staff to consider crafting breeding recommendations to facilitate mate receptivity. Encouraging more mate choice may be one way to improve receptivity and breeding success, however, the effectiveness and logistics of mate choice in ex situ populations likely requires further examination (Martin-Wintle et al., 2019). Conversely, lack of breeding behaviors may also be due to fewer staff with specialist knowledge and husbandry expertise to encourage breeding behaviors, a challenge that has been observed in some taxa (i.e., birds; Lynch & Snyder, 2014). Our findings and suggestions are intended to outline several common pitfalls in fulfilling BTP recommendations that may be addressed by institution staff, SSP Coordinators, and Population Biologists to meet ex situ conservation and population management goals.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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