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Current capacity, bottlenecks, and future projections for offsetting habitat loss using Mitigation and Conservation banking in the United States

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ABSTRACT

Habitat banking in its many iterations is an established and popular mechanism to deliver environmental offsets. The United States can look back at over 30 years of banking experience with the underlying framework and policies being consistently updated and improved. Given the increased demand in habitat banking, we provide insights into how bank area capacity is distributed across the United States for four different bank targets (wetlands, streams, multiple ecosystems, species) based on information extracted from the Regulatory In-lieu Fee and Bank Information Tracking System, as well as, estimating future capacities and area reserves through a predictive modeling approach based on data from the past 26 years. Future predictions indicate a decrease in available reserves for banks targeting wetlands or multiple ecosystems, with potential bottlenecks relating to large reserves being limited to the southeast and release schedules not catching up to the current and anticipated demand. Banks targeting species or streams are predicted to meet future demand, with species banks (conservation banks) following a different legislative and operational approach based on the listing of endangered species and pro-active approaches with anticipated future demand. Most current reserves for all four bank types are restricted to very few service areas with around one-third of all bank areas still awaiting release, limiting their availability on a broader scale. Strategic planning networks are necessary to meet future demand on a national scale and to identify areas suitable for banking or likely to experience future environmental or developmental stress.

1. Introduction

Increased land use and development and the associated loss in habitat, ecosystem function, and biodiversity have led to the implementation of legislative requirements and frameworks in many countries, to prevent further losses or utilize equivalent compensatory measures (McKenney & Kiesecker, 2009). Offsetting, aimed at simultaneously allowing anthropogenic development while ensuring appropriate mitigation and compensation measures meeting No Net loss (NNL) requirements, has been a widely implemented yet often understudied tool (Bull et al., 2013; Gardner et al., 2013). No Net Loss as a goal refers to the practice of providing mitigation or compensation measures that are equal to or outweigh the harmful impact exerted by a development project or anthropogenic activity (Bull et al., 2013; McKenney & Kiesecker, 2009; Fig. 1A). Allowing a harmful activity or project and compensating said impacts through offsetting is only permitted after following the previous steps in the mitigation hierarchy; avoidance, minimization, and restoration or rehabilitation (McKenney & Kiesecker, 2009; Fig. 1A). Offset gains can be "in-kind", meaning similar to what is lost (biodiversity; ecosystem function; habitat area) or "out-of-kind", with the latter often being a question of feasibility or flexibility (Bull et al., 2015). A proponent can be solely responsible for the offset (permittee responsible), pass responsibility to a third party (third party, e.g., credits from a bank) or has the option to pay money into a compensation in-lieu fee fund (ILF) managed by a nonprofit or government in lieu programs, which in turn use the funds for current or future offsetting activities (EPA, 1995; Fleischer & Fox, 2012; Table 1).

Abbreviations: **YAC**, Yearly Added Capacity (Area in acres/linear feet); **UCA**, Unreleased Capacity (Area in acres/linear feet); **AUR**, Accumulated Unwithdrawn Reserve (Area in acres/linear feet).

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1.1. What is habitat banking?

Habitat banking (e.g., conservation and mitigation banking) is a special case of the traditional offsetting mechanism, has gained significant traction over the past decades (Santos et al., 2015). While habitat banking follows the same mitigation methods and mitigation hierarchy as regular offsetting practice dictates (Bull et al., 2013; Fig. 1), these created, enhanced, restored, or preserved habitat areas or ecosystem functions are established, implemented and managed by a third party as opposed to the proponent itself, comprised of the bank sites, banking agreement and service area (area in which the bank can sell their credits) (EPA, 1995; Santos et al., 2015; USACE, 2008, 2015). Proponents instead purchase a required credit amount for their expected impacts, corresponding to an equal species, and ecosystem service or habitat value from the bank, set by the responding agency or government body (Burgin, 2008; Fig. 1B).

A bank needs to be approved by the responsible regulatory agency through a banking agreement and necessary permits (e.g., land disturbance permit to be able to conduct habitat restoration). The banking agreement contains all bank details of financing, sponsors, mitigation methods, and monitoring (RIBITS, 2022). Unless specified, this paper will refer to 'banks' as the sum of site, credits, agreement, and service area. Credits are generated by an Interagency Review Team (IRT) based on the banked area and the applied mitigation method (e.g., restoration; enhancement). Different credit amounts are possible as there is no universal method for defining credits, resulting in differences in environmental benchmarks against reference sites, also called net benefit, (e.g., water quality; ecological aspects; soil; vegetation). For instance, a bank restoring stream area under priority approach I (Rosgen) will have a higher credit multiplication factor than a bank restoring stream area under priority approach IV (Juracek & Fitzpatrick, 2003; RIBITS, 2022). Other factors impacting credit calculations are mitigation timing, monitoring, contingency plans, and control measures. Credits follow a release schedule relating to the bank achieving certain benchmarks like the implementation of planned in-stream modification or success criteria in the following years (RIBITS, 2022). Common monitoring approaches are based around indices of biotic integrity, indices of wellbeing, or physical habitat stability and suitability (e.g., Hughes & Gammon, 1987; Karr, 1981; RIBITS, 2022; Fig. 1B).

1.2. Current banking practices and demand in the United States

The United States banking framework is based on two different legislations leading to the establishment of mitigation and conservation banks.

1.3. Mitigation banks targeting wetlands; streams or multiple ecosystems

The earliest legislation pertains to Section 404 of the Clean Water Act (1972), aiming to protect wetlands in the United States and compensate

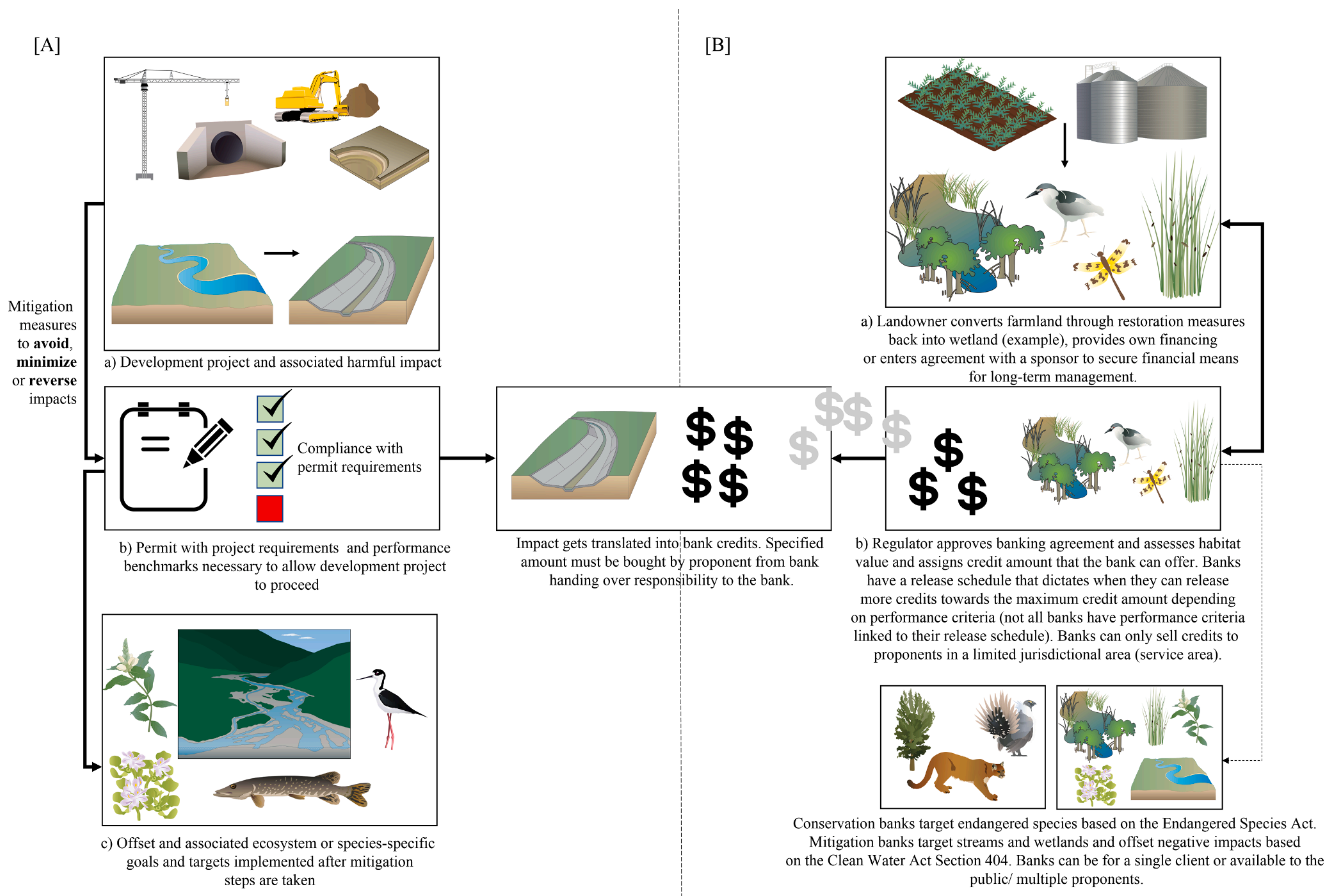

Fig. 1. Mitigation hierarchy outline, following the required steps (Avoidance, Minimization, Restoration & rehabilitation) before allowing for harmful impact to be compensated for through an equivalent or larger offset (A). (B) Banking principle and role of banking credits in the traditional offsetting scheme through translating losses into credit amounts and key bank components and the two main bank types (Conservation; Mitigation) in the United States (based on FWS, 2003; McKenney & Kiesecker, 2009; RIBITS, 2022; Vaissière & Levrel, 2015). (Digital symbols attribution Jane Thomas, Integration and Application Network; Dieter Tracey, Terrestrial Ecosystem Research Network Australia; Kim Kraeer, Lucy Van Essen-Fishman, Integration and Application Network; Tracey Saxby, Integration and Application Network; Jane Hawkey, Integration and Application Network; Sally Bell; Jason C. Fisher, University of California Los Angeles; Dieter Tracey, Marine Botany UQ; (ian.umces.edu/media-library).

Table 1
Overview of key definitions for bank types in RIBITS as well as according to bank targets, divided into Mitigation and Conservation banks targeting Wetlands; Streams; Multi-Ecosystems and Species. Extracted and calculated main variables (bank metrics) for the bank types based on 1636 assessed banks (Added Capacity (YAC); Unreleased Capacity (UCA) and Available Unwithdrawn Reserve (AUR)).

Bank types:		Reference: RIBITS; FWS; EPA; USACE	
Mitigation	**Conservation**	**ILF (In-lieu fee program)**	**Umbrella**
A site where wetlands, streams, or riparian areas are established, rehabilitated, enhanced, or preserved in order to offset authorized by the Department of Army permits.	Permanently protected sites managed for endangered species, threatened species, or species at risk. The aim is to offset adverse impacts to the protected species occurring off-site. Permits managed by FWS.	Rehabilitation, establishment, enhancement, and/or preservation of habitat area or ecosystem function through funds paid to a governmental or non-profit natural resources management organization. The operation and use of an in-lieu fee program are governed by an in-lieu fee program instrument thus differing from mitigation banks as well as allowing out of kind mitigation.	One banking instrument that dictates general requirements for an array of current and future sites (e.g., management and oversight of individual site plans to add future sites to the program).

Bank types according to bank targets:

Mitigation banks			**Conservation banks**
Wetland (n = 897)	**Stream (n = 253)**	**Multi-Ecosystem (n = 385)**	**Species (n = 101)**
Targeting wetlands	Targeting riverine systems	Targeting multiple ecosystems	Targeting a specific/ multiple species

Extracted main variables: Bank Number & Bank transactions linked to impacts
Bank numbers

n = 1636	The number of approved banks post 1995 sites divided into the 4 Bank types with transaction and bank information to calculate bank metrics.

Bank metrics (yearly basis 1995 to end of 2020 and for each of the 4 Bank types)

Yearly added capacity: Number of new banks per bank type in a year and their size (acres; linear feet for stream area). E.g. 23 Wetland banks established in 1998 with a total size of 4221 acres.

Indicator: Indication for new bank numbers and bank size. Captures trends if bank size and bank numbers increase or decrease over time (*supply bottleneck*).

Unreleased capacity (UCA): Area for each bank type in a given year that was not approved be available in credits yet either due to a release schedule or the bank not meeting performance criteria. UCA is cumulative, meaning UCA from e.g. 1997 impacts total UCA for 1998, etc.

Indicator: Indication for how fast bank release schedules are or how well banks meet performance criteria. UCA outpacing AUR indicates higher demand and slower release, potentially creating bottlenecks of unreleased area (*release bottleneck*) for specific bank types.

Available Unwithdrawn Reserve (AUR): Area for each bank type in a given year that is available to be withdrawn in credits. AUR is cumulative, meaning AUR from e.g. 1997 impacts total AUR for 1998, etc.

Indicator: Indication for demand, e.g.: are credits for a specific bank type being withdrawn, or are they just accumulating/ unused while being available. AUR outpacing UCA indicates low demand for specific bank types/ demand not exceeding credit release or bank establishment. High AUR for a specific bank type could indicate a demand bottleneck (*demand bottleneck*) or regional restrictions based on bank location and service area (*regional bottleneck*).

Credit release schedule: specifications of benchmarks and performance milestones that are necessary to be met by a bank to release further area in the form of credits. Mitigation and conservation bank release schedules have commonly comprised a mix of ecological criteria (management plan) and operational aspects: e.g. easement and financial assurance). Advance credits can be issued through in-lieu fee programs prior to providing the actual mitigation benefit or gain.

for negative impacts, with negative impacts permitted through the United States Army Corps of Engineers (USACE). Mitigation Banks refer to banks selling credits used to offset negative impacts on streams or wetlands (EPA, 1995; Stein, 2000; USACE, 2008, 2015; Table 1). There are many advantages for mitigation banks over traditional offsets, including: perpetual contracts and long-term management of the banked area as well as being able to protect larger connected areas, as opposed to multiple spaced out and not connected offset parcels. Also, purchasing credits before the impact approval can reduce the time for a proponent to receive their impact permit thus providing potential business advantages (e.g., Berlin & Malone, 2019; Field, 2015; White, 2012). Mitigation banks have been widely established throughout the United States for instance to protect coastal wetlands and stream areas in the Southeast or to compensate for urbanization in the metropolis area of the Northeast or agricultural land development in the Midwest impacting vital ecosystems like prairie wetlands (Dahl, 1990, 2000; FWS, 2013a, 2013b, 2014). While widely adopted, mitigation banking faces certain pitfalls and controversies, both ethically as well as operational and administrative (Bull et al., 2013; Maron et al., 2016). These persisting issues mostly concern the lack of transparency in reporting for impact to offset types as well as credit prices and monitoring reports (Quétier & Lavorel, 2011), poorly designed metrics for the area to credit conversion, and a general tension between supporters of environmental versus economic priorities (Maestre-Andrés et al., 2020), and the lack of long-term funds to meet the perpetuity requirements (Boisvert, 2015).

1.4. Conservation banks targeting species listed under the endangered species Act

Conservation banking, modeled after mitigation banking, and based on the Endangered Species Act (ESA; 1973), refers to landowners permanently protecting habitat for listed species. For example, credits can be sold to proponents affecting species listed under ESA can be used to restore, enhance, or protect habitat somewhere else. Conservation banks are approved by the Fish and Wildlife Service (Fox & Nino-Murcia, 2005; FWS, 2003; Table 1). Differing from mitigation banking, conservation banks predominantly rely on preserving habitat for species listed under the ESA, with demand being mainly driven by said listings, credit prices for different species, and development impairing species and their habitat (e.g., Bunn et al., 2014; Fleischer & Fox, 2012; FWS, 2013a, 2013b; Poudel et al., 2019).

Conservation banks have the advantage of permanently protecting habitats for endangered or threatened species while increasing connectivity between patchy habitats. However, like mitigation banking, preservation, rather than creating new habitat is a main concern for conservation banks, as the question of how preservation leads to No Net Less remains uncertain. Economic drivers such as price per acre per species vary greatly and have led to imbalances in conservation efforts, with the focus on 'expensive' species. Conservation bank establishment, conservation outcomes, and success criteria are still debated (Fleischer & Fox, 2012; Poudel et al., 2019) with newer amendments to the Endangered Species Act from 2016 being officially withdrawn as of July 2018. Another noticeable development is the passing of Bill 2087 in California which allows for large-scale mitigation credit establishment through Regional Conservation Investment Strategies by the FWS in the future (Assembly Bill No. 2087; 2016).

1.5. Future interest & demand – Is the future of banking secure?

Given the different legislations and targets, four major bank types are common in the United States, mitigation banks targeting wetland, streams, or multiple ecosystems and conservation banks targeting species. While advantages and issues for mitigation and conservation banks have been discussed to a great extent in the literature, another extremely important component: demand and supply, has been largely left unassessed, especially on a national level (Poudel et al., 2019; Saeed, 2004; Sapp, 1995; Scodari et al., 1995). As popularity and incentives for mitigation and conservation banking increase, coupled with the necessity of offsetting increased anthropogenic impacts, so does the demand and supply. Consequently, the number of banks in the United States has increased steadily over the past 30 years (Poudel et al., 2018). The question is how does demand and supply relate to one another, and is the future of banking secure? Understanding how both bank types (mitigation and conservation) and their specific targets operate in the United States and whether the current banking trends and performance will meet the increasing demand will improve existing and future guidance and policy decisions and help set the path for the future.

Here we aim to answer the following research questions to assess current and future banking potential for conservation and mitigation banks: (1) Based on trends from the past 26 years, what are future predictions for bank reserves (currently available area) and, unreleased capacity (maximum available area in the future) across different bank types divided into mitigation banks (wetlands; streams' multiple ecosystems) and conservation banks (species)? (2) Which regions hold potential reserves and unreleased capacity and where or for what bank types are capacity bottlenecks likely to occur? Given the high demand for banking credits in combination with banking being an established and consistently updated practice and the large proportion of degraded habitat in the United States being suitable for banking through restoration, we hypothesize that banks will be able to meet future demand based on newly added banks, bank size and operating capacities through forecast predictions (e.g., Poudel et al., 2018 & 2019; RIBITS, 2022).

2. Methods

2.1. Dataset

Data for this study was acquired through the Regulatory In-Lieu Fee and Banking Information Tracking System (RIBITS), extracting information on 4055 banks and ILFS sites for the United States (last accessed December 18th, 2021). Only approved banks were included in this study to estimate current and future capacities, as well as banks having information on size, credit availability, and ledger transactions as well as bank type associated with them (Table 1). Furthermore, banks established before 1995 were excluded from the analysis due to the previous use of a non-uniform reporting system. We used bank data and transactions up to December transactions 31st 2020, basing predictions on whole years. Overall, the sorting process yielded 1636 banks with the necessary information available.

2.2. Key variables

2.2.1. Bank types

We divided the 1636 conservation and mitigation banks by their RIBITS designations which refer to targets. Mitigation banks were subdivided into banks targeting wetlands (Wetland; n = 897), streams (Stream; n = 253) or multiple ecosystems (Multi-Ecosystem; n = 385). Due to the low sample size, we combined conservation banks that target single or multiple species (Species; n = 101; Table 1).

2.2.2. Current and future predictions for capacity and reserves – Bank metrics

Bank metrics for current and future capacity and reserve were *Yearly Added Capacity (YAC)*, *Unreleased Capacity* (UCA), and *Available Unwithdrawn Reserve* (AUR).

2.2.3. Yearly added capacity (YAC)

Yearly Added Capacity (YAC) is based on the number of new banks each year per bank type and their -area (Acres; Linear feet for Stream banks; Table 1). Incorporating bank number and size into this metric allows us to identify trends on whether bank size and number increase or decrease over time and how potential trends could play into future predictions. For instance, an increasing trend in bank numbers and size over the past 26 years would a) indicate an increasing demand in banking, as well as advances in policies that allow for bank establishment, and b), would indicate a likely future increase in yearly added bank numbers and size. *Yearly Added Capacity* is not cumulative, as it is calculated for each year independently (1995 to 2020).

2.2.4. Unreleased capacity (UCA)

This metric is based on the area for each bank type each year that has not been yet approved for release through credits (Table 1). For instance, a wetland bank founded in 1998 with 100 acres and 25 acres released would have a UCA of 75 acres in that year. UCA is due to release schedules and performance criteria that determine when and how much of a bank area can be released in the form of credits to be available for proponents. It is a useful indicator metric since it captures how fast bank release schedules are or how well banks meet performance criteria. UCA is a cumulative metric, meaning UCA from the previous year affects UCA for the next year.

2.2.5. Available Unwithdrawn Reserve (AUR)

The metric is based on the area for each bank type each year that is available to be withdrawn in the form of credits bought by proponents (Table 1). For instance, if a species bank had 45 acres of released area available that was not withdrawn in 2002, that would respond to its AUR. AUR is a cumulative metric, meaning AUR from the previous year carries over to the next year until withdrawn.

2.2.6. Bottlenecks

UCA outpacing AUR indicates higher demand and slower release, potentially creating bottlenecks of unreleased areas (*release bottleneck*) for specific bank types. AUR outpacing UCA indicates low demand for specific bank types/ demand not exceeding credit release or bank establishment. High AUR for a specific bank type could indicate a low demand (*demand bottleneck*) or regional restrictions based on bank location and service area (*regional bottleneck*). A decrease in YAC indicates a decrease in newly established banks per year and/ or bank size, consequently affecting UCA and AUR. For instance, if no banks are established in 2022, AUR and UCA would consequently decrease (*supply bottleneck;* Field, 2015; Poudel et al., 2018; Watson et al., 2019).

2.3. Statistical analysis

2.3.1. Future predictions for YAC, UCA, and AUR across bank types

Future predictions for YAC, UCA, and AUR were done through univariate time series modeling, based on the 26 years of data we extracted, through Auto-Regressive Integrated Moving Average (ARIMA) modeling, in R (4.1.0 R Core team, 2020; Appendix 1). The ARIMA model is generally used to derive information from past data to inform future predictions (Hyndman & Athanasopoulos, 2021). We tested and selected a total of 12 individual models (YAC; UCA and AUR for each of the 4 bank types; Appendix Table 1–4). Each model predicted YAC, UCA, or AUR for the 4 bank types up to 2030. Predictions were done on a step-by-step basis, meaning the first prediction for instance for UCA for Wetland banks for 2021 was based on the data from 1995 to 2020, and the prediction for 2022 was based on the data from 1995 to 2020 plus the 2021 prediction (Hyndman & Athanasopoulos, 2021; Hyndman & Khandakar, 2008). Each model was based on three main components (p

= is the number of autoregressive terms (AR); d = is the number of non-seasonal differences needed for stationarity; q = is the number of lagged forecast errors in the prediction equation (MA). These components determine the model fit which is measured through the Akaike information criterion (AIC), Akaike information corrected criterion (AICc), and Bayesian information criterion (BIC; Hyndman & Athanasopoulos, 2021; Hyndman & Khandakar, 2008). An in-detail example for model selection can be found in the supplements (Supplements 1).

Step one was to test for stationarity of the time series through a Dickey-Fuller test. Stationarity is a requirement that needs to be met before fitting the model. Significant results indicate that the stationarity requirement was met (Appendix 1). Non-stationarity requires a stepwise correction. The number of corrections to reach significant results for the Dickey-Fuller test determines d. For instance, stationarity without correction necessary means d = 0, one correction means d = 1. Steps 2 and 3 included determining p and q which correct for autocorrelation. In step 2, q was determined through the ACF plot (Autocorrelation plot). The ACF plot is a correlogram showing serial correlation changes over time in the time series data (Supplements 1). Lags meeting significance in the plot determine p. For instance, an ACF plot with 2 lags meeting significance would result in p = 2. The same approach was used for q and the PACF plot (Partial autocorrelation plot). In step 4, after ensuring stationarity and determining appropriate p, d, and q terms for each model, AIC, AICc, and BIC were compared with other models provided by the auto function from the forecast package to rule out errors and ensure the fit model was selected. The final step was to check each model's residuals through a Ljung-Box test for autocorrelation of the residuals (non-significant results indicate no autocorrelation of residuals). After that, each of the 12 models was run to predict YAC, UCA, and AUR for the 4 bank types and forecasts plotted with 80 and 95% confidence intervals (Hyndman & Athanasopoulos, 2021; Hyndman & Khandakar, 2008). Current trends and future predictions for YAC, UCA, and AUR are meant to identify *release bottlenecks, demand bottlenecks,* and *supply bottlenecks.* Trends in YAC, UCA, and AUR between 1995 and 2020 were analyzed through linear models (Response variable: YAC; UCA; AUR; Predictor variable: Year). Significant increases or decreases were identified through accepted Alpha values of 0.05 and effect size estimated by r-squared values (R^2; Hamilton et al., 2015).

2.3.2. *Current reserves and capacities across bank types and regions*

To showcase the status of the 4 bank types, we calculated the proportionate amount of withdrawn area for each bank type (not available anymore since sold to proponents) compared to UCA and AUR. Plotted as pie charts these estimates show if a specific bank type currently exhibits notable trends in terms of withdrawn or available area. If Wetland banks for instance had 99% of their total possible area withdrawn it would indicate a severe lack of currently available reserves (AUR) and future capacities (UCA). *Regional bottlenecks* and areas of high reserves were identified through selecting the top 100 banks with the highest AUR and UCA area values as of 2020, related to their designated bank type (Wetland; n = 56; Stream; n = 11; Species; n = 19; Multi-Ecosystem; n = 14) and mapped in GIS to capture their location and service area. Total capacity (all bank areas for a bank type summed), UCA, and AUR were related to the overall proportion for each bank type. For instance, in an example, all Wetland banks (n = 897) have a summed size of 100.000 acres, UCA of 25.000 acres, and AUR of 20.000 acres. In this example, the 56 Wetland banks in the top 100 hold 60.000 acres, UCA of 10.000 acres, and AUR of 10.000 then which comprises 60% of the total Wetland bank capacity, 40% of total UCA, and 50% of total AUR. This would point to large capacities and reserves sitting with a small number of wetland banks, potentially limited to specific regions which were identified through our map.

3. Results

3.1. *Future predictions and reserves*

3.1.1. *Wetland banks*

YAC for Wetland banks over the past 26 years ranged from its lowest value of 5085 acres as part of newly established banks in 2006 to its highest yearly added value of 35,919 acres in 2015 (mean: 16,039 ± 12,986 Acres; Fig. 2A). There was no significant increase or decrease in YAC from 1995 to 2020 ($p = 0.254$; $R^2 = 0.015$; Table 2; Appendix Table 5). Results from the ARIMA model for YAC for Wetland banks (1;1;1; AIC 552.65; Appendix Table 1) show that YAC for Wetland banks is predicted to be at 16,554 Acres (95% CI: −13,426|46,535 Acres) in 2030 which is an increase of 3.2% from the previous yearly mean (Fig. 2A; Table 2). UCA for Wetland banks increased significantly over the past 26 years from 9546 Acres in 1995 to 129,884 Acres in 2020 ($p < 0.001$; $R^2 = 0.88$; Table 2; Appendix Table 5; Fig. 2A). Future predictions from the ARIMA model (1;2;1; AIC 475.59; Appendix Table 1) show that UCA is predicted to increase to 175,258 Acres by 2030 (95% CI: 66,613|283,903 Acres) marking a 34.9% increase (Table 2). Like UCA, AUR increased significantly over time from 4543 Acres in 1995 to 106,871 Acres in 2020 ($p < 0.001$; $R^2 = 0.96$; Table 2; Appendix Table 5; Fig. 2A). The ARIMA model (2;2;3; AIC 475.59; Appendix Table 1) suggests an AUR reduction of 30.1%, to 74,808 Acres by 2030 (95% CI: −35,827|185,444 Acres; Table 2). Overall, YAC is predicted to stay consistent for Wetland banks by 2030 with UCA further increasing and AUR decreasing, reducing available reserves by 2030.

3.1.2. *Stream banks*

YAC for Stream banks, measured in Linear Feet varied greatly over the past 26 years from 2942 Linear Feet in 2004 to 2,315,912 Linear Feet added in a single year in 2012 (mean: 886,495 ± 1,139,603 Linear Feet; Fig. 2B). Stream banks were not listed before 2001. Overall, YAC increased significantly up to 2020 ($p < 0.05$; $R^2 = 0.27$; Table2; Appendix Table 6; Fig. 2B). Future predictions for YAC for Stream banks (ARIMA 0;1;1; AIC 757.83; Appendix Table 2) suggest an increase to 953,537 Linear Feet (95% CI: −2,082,203|3,989,277 Linear Feet) in yearly established new Stream bank area (7.6% increase from 1995 to 2020 yearly mean; Table 2). UCA for Stream banks increased significantly over time from 1167 Linear Feet in 2001 to 6,648,679 on 2020 ($p < 0.001$; $R^2 = 0.77$; Table 2; Appendix Table 6; Fig. 2B). Predictions for 2030 (ARIMA 1;2;3; AIC 724.74; Appendix Table 2) show a continued increase by 38.6% to 9,212,782 Linear Feet (95% CI: 2,226,190|16,199,373 Linear Feet; Table 2). AUR increased from 11,561 Linear Feet in 2001 to 1,324,203 in 2020 ($p < 0.001$; $R^2 = 0.83$; Table 2; Appendix Table 6). AUR is predicted (ARIMA 2;2;3; AIC 668.47; Appendix Table 2) to increase from its 2020 level by 42.1% to 1,881,987 Linear Feet (95% CI: 701,462|3,062,512 Linear Feet; Table 2). Overall, YAC, UCA, and AUR for Stream banks have been increasing over the past 26 years and are predicted to follow that trajectory for the next 10 years.

3.1.3. *Multi-ecosystem banks*

Multi-Ecosystem banks increased in YAC from 1995 to 2020, ranging from 481 Acres established in 1996 to 14,535 Acres in 2011 (mean: 5076 ± 4204 Acres; Fig. 2C). While the increase over the past 26 years was significant ($p < 0.05$; $R^2 = 0.22$; Table 2; Appendix Table 7), YAC for Multi-Ecosystem banks is predicted to decrease by 32.7% by 2030 to 3417 Acres (95% CI: −12,220|19,055 Acres; Table 2) of yearly added Multi-Ecosystem bank area (ARIMA 1;1;0; AIC 486.35; Appendix Table 3). UCA for Multi-Ecosystem banks increased significantly over the past 26 years from an initial 224 Acres to 48,870 Acres in 2020 ($p < 0.001$; $R^2 = 0.84$; Table 2; Appendix Table 7; Fig. 2C). The current (2020) UCA is predicted to almost double by 2030 (+83.3%; 89,573 Acres; 95% CI: 47,497|131,650 Acres; ARIMA 0;2;1; AIC 442.49; Table 2; Appendix Table 3). AUR increased from 123 Acres to 10,653 Acres in 2020 ($p < 0.001$; $R^2 = 0.74$; Appendix Table 7; Fig. 2C). Future

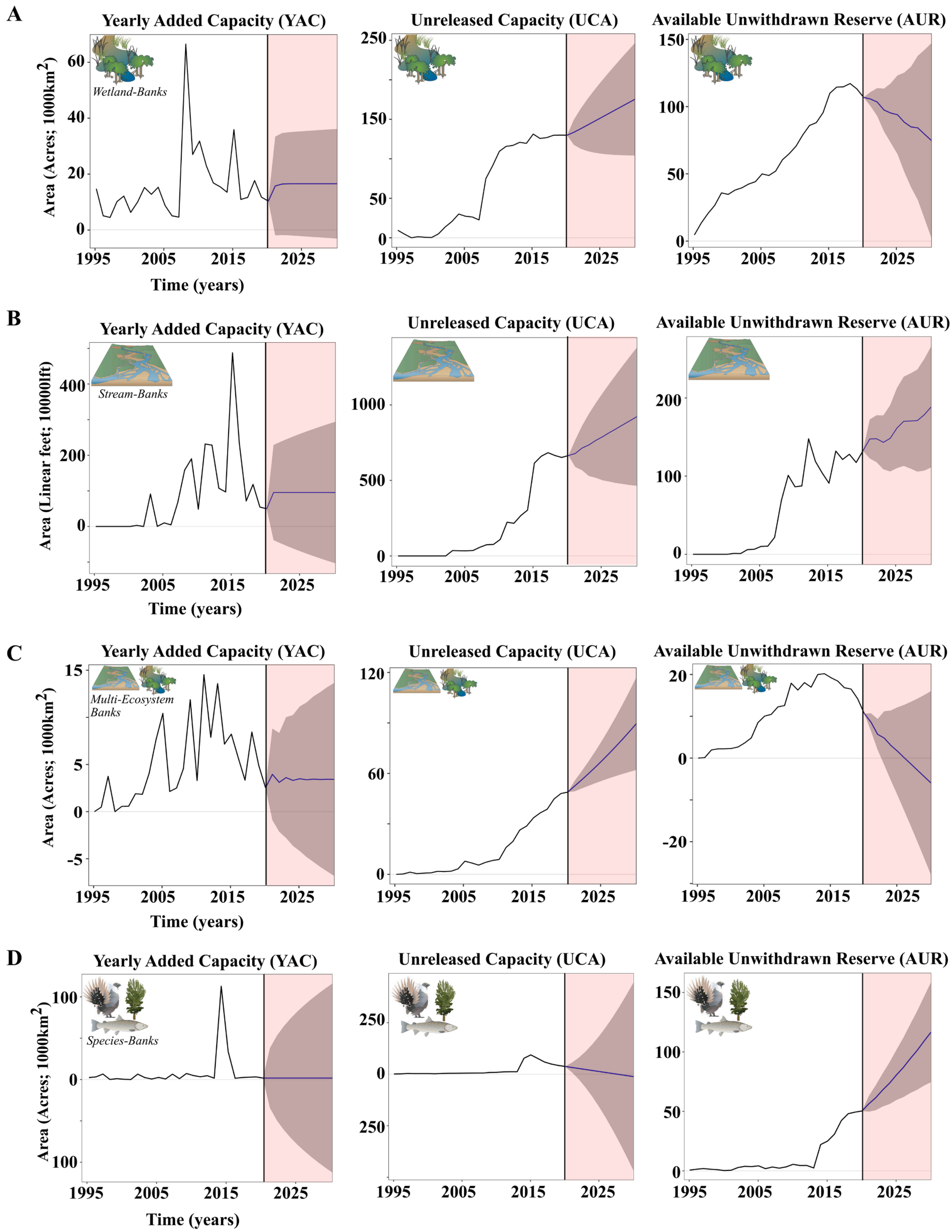

Fig. 2. Plotted Yearly Added Capacity (YAC); Unreleased Capacity (UCA) and Available Unwithdrawn Reserve (AUR) for the four bank types (Wetland (A); Stream (B); Multi-Ecosystem (C); Species (D)) between 1995 and 2020 based on 1636 assessed banks. Future predictions up to 2030 for all bank types based on ARIMA models (Appendix Tables 1 – 4) and 95% Confidence Intervals (Appendix Table 1 – 4; Model selection walkthrough in Appendix 1). (Digital symbols attribution Tracey Saxby; ian.umces.edu/media-library).

Table 2
Linear trends and responding significance values for Mitigation (Wetland; Stream; Multi-Ecosystem) and Conservation (Species) banks between 1995 and 2020, indicating increases or decreases in YAC, UCA and AUR (Appendix Tables 5–8). Predictions for 2030 and changes in percent (%) to 2020 amounts of YAC, UCA, and AUR. Based on ARIMA predictions (Fig. 3; Appendix 1; Supplements Tables 1–4).

	Linear trends 1995 to 2020			2020 to 2030 ARIMA predictions in %		
	YAC	UCA	AUR	YAC	UCA	AUR
Mitigation banks						
Wetland	$p = 0.254$ no change	$p < 0.001$ increase	$p < 0.001$ increase	+3.2%	+34.9%	−30.1%
Stream	$p < 0.05$ increase	<0.001 increase	<0.001 increase	+7.6%	+38.6%	+42.1%
Multi-Ecosystem	$p < 0.05$ increase	<0.001 increase	<0.001 increase	−32.7%	+83.3%	0 AUR by 2026
Conservation banks						
Species	$p = 0.264$ no change	<0.001 increase	<0.001 increase	−44%	0 UCA by 2028	+131.5%

predictions for the next 10 years (ARIMA 1;2;3; AIC 431.18; Appendix Table 3) show a steep decrease in AUR to the point of reaching 0 by 2026 (95% CI: −19,241|19,416 Acres; Table 3). While increases are predicted for newly established Multi-Ecosystem areas in the future, much of that area is predicted to contribute to UCA while available reserves in AUR are predicted to decline to the point of depletion.

3.1.4. Species banks

Species banks (conservation banks) showed a consistent YAC between 1995 and 2020 (mean: 4060 ± 22,301 Acres; Fig. 2C; $p = 0.264$; $R^2 = 0.012$; Appendix Table 8) apart from 2014 (>100,000 Acres established in a single bank). Results from the ARIMA model for YAC for Species banks (0;1;0; AIC 585.54; Table 2; Appendix Table 4) show that YAC for Species banks is predicted to decrease to 1788 Acres (95% CI: −173,229|176,806 Acres) in 2030 which marks a decrease of 44% from the previous yearly mean (Fig. 2D; Table 2). UCA for Species banks increased from around 1000 Acres in 1995 to 37,686 Acres in 2020 ($p < 0.001$; $R^2 = 0.51$; Table 2; Appendix Table 8; Fig. 2D). UCA is predicted to decrease over the next 10 years with approaching 0 by 2028 (−1696 Acres; 95% CI: −509,714|506,322 Acres; ARIMA 0;2;0; AIC 540.81; Table 2; Appendix Table 4). AUR similarly to UCA increased over the past 26 years from 622 Acres to 50,324 Acres as of December 31st, 2020 ($p < 0.001$; $R^2 = 0.62$; Table 2; Appendix Table 8; Fig. 2D). Compared to the predicted decrease in UCA, AUR for Species banks is predicted to increase up to 116,550 Acres (95% CI: 52,382|180,717 Acres) in 2030 (ARIMA 1;3;3; AIC 474.17; Appendix Table 4). This predicted area constitutes a 131.5% increase from the current AUR (Table 2). Species banks are predicted to slightly decrease in their yearly added capacity while potentially moving large areas from unreleased to released, reducing UCA while increasing AUR.

3.2. Current reserves and capacities across bank types and regions

3.2.1. Reserves and capacity availability across bank types

Out of the total area that has been added through Wetland bank (mitigation banks) establishment (assessed n = 897) between 1995 and 2020, 43% were withdrawn as part of proponent transactions and are no longer available. 26% of the proportionate total bank area is currently available to be bought as credits and 31% may become available in the future depending on release schedules and performance criteria (Fig. 3A). 65% of the total Stream bank (mitigation banks) area (assessed n = 253) from 1995 to 2020 has been withdrawn so far with 29% awaiting future release and a current reserve of 6% of total Stream bank area, recorded in Linear Feet (Fig. 3B). Assessed Multi-Ecosystem banks (mitigation banks; n = 385) between 1995 and 2020 had more than half of their total established area (55%) withdrawn for 55%. 37% of the

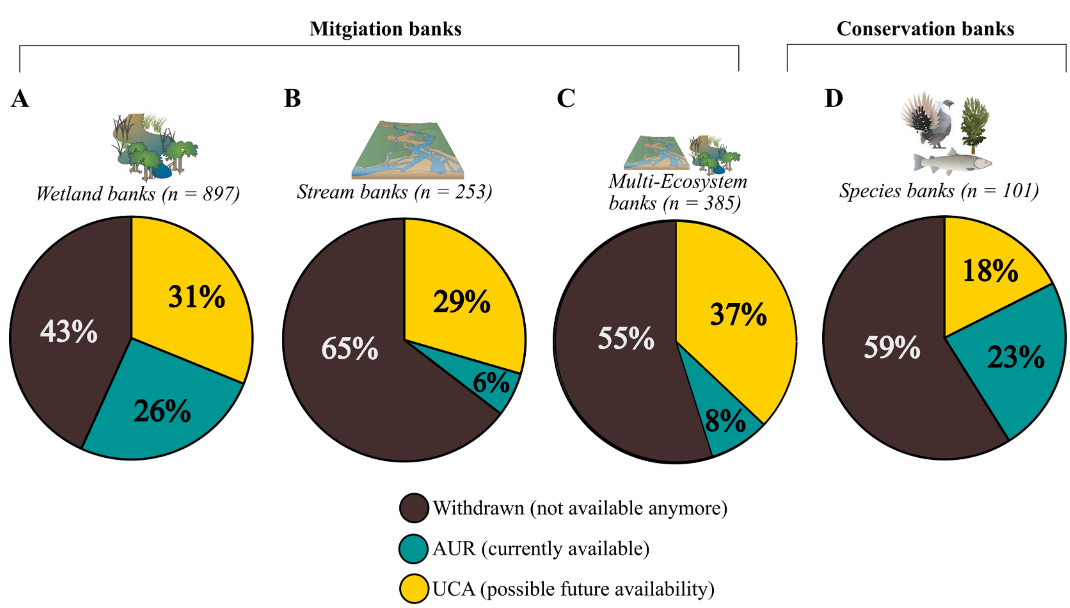

Fig. 3. Withdrawn area through credit transactions between proponent and bank in contrast to Unreleased Capacity (UCA) and Available Unwithdrawn Reserve (AUR) for the four bank types (Wetland (A); Stream (B); Multi-Ecosystem (C); Species (D)) based on totaled data from 1995 and 2020 based on 1636 assessed banks. (Digital symbols attribution Tracey Saxby; ian.umces.edu/media-library).

total area is currently unreleased and 8% are available for proponent credit transactions to be used for offsetting approved negative development impacts (Fig. 3C). Finally, Species banks (conservation banks) have a current reserve of 23% of their total established area, 18% currently unreleased, an overall 59% withdrawn in transactions between 1995 and 2020 (Fig. 3D). The highest current reserves (AUR) across bank types were attributed to Wetland and Species banks, while Wetland and Multi-Ecosystem banks have the currently highest proportion of yet unreleased area (UCA). Species and Stream banks had the most proportionate area withdrawn between 1995 and 2020.

3.2.2. *Regional distribution of reserve and capacity hotspots*

Mapping the top 100 banks contributing to UCA and AUR showed that the majority were Wetland banks (n = 56) followed by Species banks (n = 19), Multi-Ecosystem banks (n = 14), and Stream banks (n = 11; Fig. 4). These 56 Wetland banks comprising 6% of all assessed Wetland banks are currently holding 58% of all established and assessed Wetland bank area between 1995 and 2020 (~243,000 Acres) and 51% of total AUR (~54,000 Acres), as well as 69% of UCA (~89,000 Acres). The main distribution for these Wetland banks was in the Southeast of Texas; Southeastern Louisiana; Mississippi, Georgia, and Florida (Fe 4a). The 19 Species banks (19% of all assessed Species banks) cover an area of 185,000 Acres (86% of total Species bank area), as well as 86% of all AUR (~43,000 Acres) and 92% of UCA (~35,000 Acres). Most of these banks were in central Texas, Oklahoma, Southern Florida, and California with single banks in Wyoming, Maine, and Kansas (Fig. 4A). The total established area for the 14 assessed Multi-Ecosystem banks (3.5% of all Multi-Ecosystem banks) comprises 27% of the total established area between 1995 and 2020, 39% of total AUR (~4000 Acres), and 35% of total UCA (~17,000 Acres). These 14 banks were in Northeast Texas, Mississippi, Florida, and Georgia (Fig. 4A). Finally, the 11 Stream banks (4% of all Stream banks) located in Mississippi, West Virginia, North Carolina, and South Carolina held 63% of the total Stream bank area (14,130,000 Linear Feet), 58% of total AUR (756,000 Linear Feet), and 68% of total UCA (4,551,000 Linear Feet). These 100 banks contributing the most to AUR and UCA overlap with the general banking distribution in the United States, identifying especially the Southeast, parts of the Midwest, and the West-Coast as baking hotspots in terms of density (Fig. 4B).

4. Discussion

We identified several key findings related to our hypotheses that are summarized here:

Yearly added Capacity (YAC) has been consistent for Wetland and Species banks and overall increased for Multi-Ecosystem banks and Stream banks. Unreleased Capacity (UCA) has accumulated between 1995 and 2020 for all four bank types. Future predictions suggest a similar trend for 2030 for Mitigation banks (Wetland, Stream, and Multi-Ecosystem banks) while predicting a decrease in UCA for Conservation (Species) banks. Available Unwithdrawn Reserves (AUR) increased over time and are predicted to decrease greatly for Wetland and Multi-ecosystem banks by 2030, while predicted to increase for Species and Stream banks. As of December 31st' 2020, Wetland banks and Species banks had the largest proportionate amount of AUR compared to the overall available banking area for each respective type. Stream and Multi-ecosystem banks showed low percentages of total bank area being available in reserves. The bank area with possible future availability (UCA) was the highest for Wetland and Multi-ecosystem banks and the lowest for Species banks. Banks contributing the most to AUR and UCA were mostly Wetland banks. The largest Wetland and Multi-Ecosystem banks AUR and UCA are currently sitting in the Southeastern United States. Species bank AUR and UCA were predominantly associated with the Western United States, namely Wyoming, California, and Texas. Areas for large Stream bank AUR and UCA were in the South and along the Eastern Seaboard. Overall AUR and UCA for all four bank types are linked to a few individual banks and specific states and regions compared to the overall number of 1636 assessed banks.

4.1. *Wetland banks and multi-ecosystem banks – High capacities but decreasing reserves?*

Wetland and Multi-ecosystem banks showed similar past and predicted future trends concerning UCA and AUR as well as spatial distribution for reserve and capacity hotspots. Both bank types showed constant and/ or increasing yearly added capacity (YAC), with both bank types having large increases of UCA over time (currently ~ 30% of the total established area; Fig. 3 A; C), which makes a *supply bottleneck* unlikely. However, AUR is predicted to decline sharply by 2030, which also speaks against a *demand bottleneck*. The scenario of declining reserves could potentially come true because newly established banks are not able to release areas in the form of credits fast enough due to release schedules or not meeting performance criteria, with accumulating unreleased areas outpacing the available area that constitutes the current reserves as shown in the results. Both bank types have already passed the turning point in the past five years, with AUR declining. In

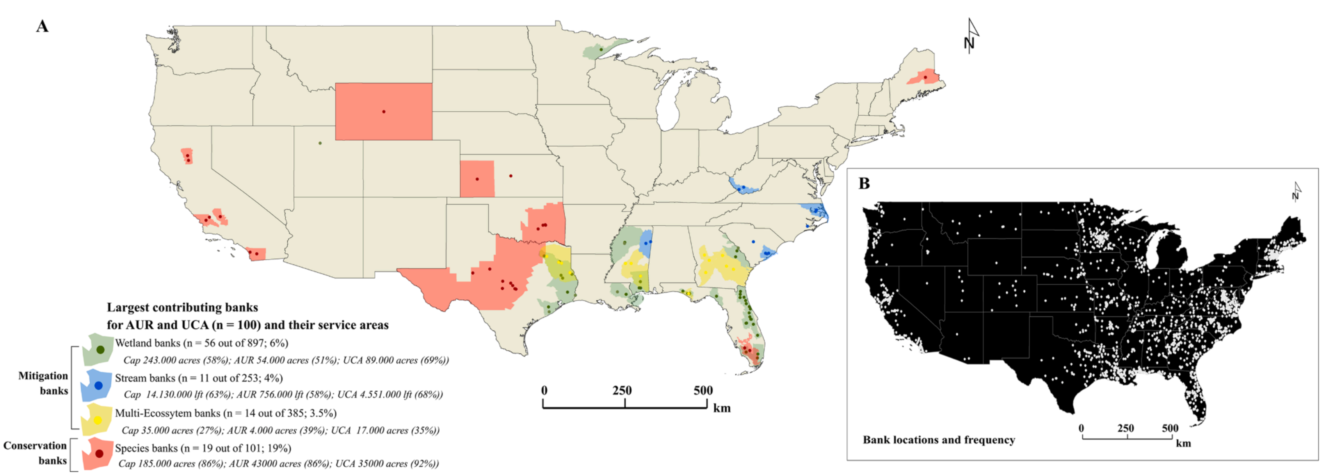

Fig. 4. (A) Mapped bank location and service area for the top 100 highest Unreleased Capacity (UCA) and Available Unwithdrawn Reserve (AUR) contributing banks across the four bank types (Wetland; Stream; Multi-Ecosystem; Species) based on totaled data from 1995 and 2020 based on 1636 assessed banks. Individual banks can have multiple locations as primary and secondary etc. bank areas. UCA; AUR and total encompassing bank area for each bank type in the n = 100 subset are compared to the overall UCA; AUR and total bank areas for each bank type n = 1636. (B) Bank distribution (location) across the United States based on geospatial data extracted from RIBITS.

the case of Wetland and Multi-Ecosystem banking, this would mean a *release bottleneck*. This issue is supported by other studies and the general literature, pointing out that release schedules and bank operation can often change over time and range from switches in bank sponsor to changes in area allocation to bank failure and potential closure in the future (e.g., Gardner et al., 2013; Reiss et al., 2009; Vaissière et al., 2017). For instance, a study from Florida, where large proportions of our studies' Wetland bank UCA and AUR were located, found that while mitigation bank compliance was over 40%, 17% of the assessed banks were unlikely to meet permit criteria. Furthermore, credit release was often not or insufficiently tied to ecological criteria but rather financial or operational benchmarks (Reiss et al., 2009). This potentially can act in two ways. On the one hand, credit release predominantly tied to financial assurances can lead to a fast credit release, meeting the high demand in the Southeast (e.g., Reiss et al., 2009; Sapp, 1995; Scodari et al., 1995). On the other hand, the high level of uncertainty for ecological functionality in combination with non-compliance could lead to delays in credit release and accumulation of UCA in other parts. This could explain the current declining AUR trends, where fast credit release for some banks seems insufficient to compensate for delays in release schedules for Wetland and Multi-Ecosystem banks.

Another aspect to factor in is ownership. An estimated 75% of all wetlands in the continental United States are privately owned (Scodari et al., 1995). Turning private land owned by a multitude of smaller stakeholders into banks or acquiring larger portions for Umbrella banks could delay the operating process further, explaining longer startup time for Wetland and Multi-Ecosystem banks (Bunn et al., 2013; Grimm, 2020). Finally, there is regionality. The highest reserves and unreleased capacities for Wetland and Multi-Ecosystem banks were in the Southeast, especially Florida, Georgia, Mississippi, and Southeast Texas. While the demand for protecting and mitigating impacts to ecologically valuable and vital wetlands in the Southeast is high, it is somewhat worrisome that capacities and reserves seem to be almost exclusively limited to this region. UCA and AUR in these regions make up around 50% of the total UCA and AUR of all assessed Wetland and Multi-Ecosystem banks. For instance, states like Michigan, containing vital wetland reserves, do not field any mitigation banks and potentially could benefit greatly from being incorporated into the current banking network (FWS, 2013a, 2013b; 2014). This becomes even more important when considering that agriculture induced land-sue changes are predicted to be significant in coming decades in the Midwest (FWS, 2013a, 2013b; 2014).

Another factor in the case of the large amount of UCA in the Southeast is most likely due to future anticipated demand in mitigation credits. Final rules from USACE and EPA in 2008 state a preference for mitigations banking as opposed to ILFs or proponent led offsetting, signaling both developers as well as bankers the need to secure more area for banks (Pittman & Waite, 2009; USACE, 2008; Vaissière et al., 2017). Long-term anticipation and regulatory favoritism hold a potential danger for these banks and areas since regulations and frameworks are constantly changing and so are market dynamics and development needs. In a worst-case scenario, triggered by a switch from banking towards alternative measures, as well as decreasing prices, these large wetland areas could simply stay unrestored and unmanaged. Vice, versa a banking boom would also reduce investment and advancement of alternative offsetting tools which could also increase competition amongst banks, wanting to release their anticipated credits, leading to bank failure and closures (Pittman & Waite, 2009; Robertson, 2004; Vaissière et al., 2017). Our predictions show that in the case of Wetland banks, large accrued past reserves should be sufficient in compensating for release delays or future anticipated impacts. While past and current demand for Wetland banking credits is high, large-scale establishment especially in the Southeast is likely equally seen as a preservation measure for future anticipated impacts (e.g., Reiss et al., 2014; Spieles, 2005). Multi-Ecosystem banks however in a worst-case scenario, given past trends and data, would be depleted by 2030 due to lower reserves and the increased demand for more complex and diverse ecosystem services provided through banks (e.g., Dadisman, 2020; Deal et al., 2012). An increase in Multi-Ecosystem banks and associated credits would be supported by an increased call for matching spatial, ecological and administrative aspects better as well as incorporating feedback loops across systems and landscapes to allow for synergetic benefits (e.g., Henle et al., 2010; Moilanen et al., 2005). Multi-Ecosystem approaches have become more and more important especially in the context of urbanized landscapes and temporary ecosystems (e.g., temporary streams; temporary wetlands; Calhoun et al., 2017; Qiu & Turner, 2013).

4.2. Stream banks – Stream rehabilitation in the United States

Stream mitigation banks showed a different trend from Wetland and Multi-Ecosystem banks in terms of predicted increases in accumulated reserves coinciding with increases in unreleased capacity in the future. This predicted increase in reserves in Linear Feet based on past data could be linked back to stream banking increasing more recently (the early to mid-2000s) in popularity as opposed to Wetland mitigation banking as well as operational differences (Julian & Weaver, 2019; Lave et al., 2008). Stream mitigation banking heavily relies on habitat rehabilitation and is often aimed at degraded urban streams are agriculture adjacent (e.g., Lave, 2021; Theis et al. unpublished). These often-small streams are aimed to be restored through management through a banking agreement. Small scale and tangible goals through restoration could foster faster release schedules and realization of stream mitigation banks compared to some of the larger Wetland mitigation banks or approaches including ecosystem establishment, struggling from well-known and still persistent issues with long-term ecological processes or over-simplification of wetland complexity and bank failure (e.g., Mateos, 2018; Whigham, 1999).

Large scale stream mitigation banks on the other hand are often part of overarching land-use planning strategies on a watershed level (e.g., BenDor & Riggsbee, 2011; Chastant, 2007; Glickauf & Keebaugh, 2009; Harding, 2001). Banks being part of land-use planning strategies is still new but more and more common for Stream banks and holds the unique advantage of considering surrounding development and residential impacts, better financial and operational means, and overall better connectivity to the rest of the watershed and its ecological processes (e.g., Chastant, 2007; Glickauf & Keebaugh, 2009; Harding, 2001). Overall current and predicted increases in demand for stream mitigation banking area and credits paired with a faster turn-around time and credit release potentially based on favoring rehabilitation over ecosystem establishment could explain the predicted scenario for 2030. Current reserves for stream banks only made up 6% of the total banked area, suggesting that given its relative novelty, stream mitigation banking is not yet as mature compared to for instance wetland mitigation banking, providing another explanation for the future predictions with stream mitigation banking eventually reaching a point where reserve usage will be outpaced by the accumulation of unreleased area and credits. Using rehabilitation over ecosystem establishment and its issue of potentially missing ecological equivalency are not considered in this scenario (e.g., Fox & Nino-Murcia, 2005; Grimm, 2021; Vaissière et al., 2017). Stream mitigation banking's popularity in the Southeast aligns with findings from current literature (e.g., Chastant, 2007; Glickauf & Keebaugh, 2009; Harding, 2001; Lave, 2021; Lave et al., 2008). Overall capacity, UCA, and AUR held by a few individual Stream banks point to similar potential bottlenecks compared to Wetland and Multi-Ecosystem banking, mainly being a regional bottleneck with chances for a *release bottleneck* in the future should Stream banking follow a similar trajectory as other mitigation banking practice. A *regional bottleneck* could be prevented by extending Stream banks to other major watersheds (especially predicted to experience future water stress) and building on existing and new land-use planning strategies (e.g., potential applications in Colorado and the West; BenDor & Riggsbee, 2011; Julian & Weaver, 2019).

4.3. Species banks – Regulatory drivers and market drivers in unison

Conservation banks, targeting single and multiple species deviate from the other trends predicting a future decline in UCA and an increase in AUR. These predictions are based on the fact that conservation banks have different operational and establishment drivers compared to mitigation banks. The main driver here is the listing of imperiled species by the Fish and Wildlife Service, often triggered by land-use change and development (FWS, 2003; Poudel et al., 2019). An example here is the greater sage-grouse (*Centrocercus urophasianus).* Though not officially listed under the endangered species act, due to a wide range of legislative issues and competing stakeholder interests (e.g., listing of large range species would impact many different economic branches), scientific evidence of large-scale habitat degradation and consequent long-term species endangerment has led to the establishment of the United States' largest single-species conservation Bank in Wyoming in 2015 (e.g., FWS, 2015; Holloran et al., 2010; LeBeau et al., 2018). Given the large range, the sage-grouse needs to maintain healthy populations, banked area, and land held by the Sweetwater River Conservancy encompass over 700,000 acres with plans to establish similar banks in other neighboring states (e.g., FWS, 2013a, 2013b). The greater sage-grouse however is an exception to the norm. Other examples, following the regular listing procedure after population imperilment through human development, are the Florida panther or vernal pool crustaceans in California (e.g., Bunn et al., 2014; Kreye & Pienaar, 2015; Poudel et al., 2019).

While Stream banks often aim at restoring degraded stream habitat and Wetland mitigation banking utilizing a wide array from restoration to the establishment, conservation banking mainly relies on habitat preservation in combination with land management and maintenance (e.g., Fox & Nino-Murcia, 2005). The example of the sage-grouse showcases that preserving large areas of the current habitat through a bank does not match currently approved impacts but is in anticipation of future impacts. Thus, release schedules will provide more and more area to be available in credits over time before the demand is there. This explains the potential large current and future reserves of species credits and decline in unreleased capacities given the sheer size of the bank compared to other conservation banks. While a wide variety of endangered species are covered by conservation banks, a large proportion is yet to be included in conservation banking with issues concerning migratory and large-range species persisting and slowly being addressed by Umbrella banks or transboundary agreements (e.g., for migratory bird and bat species; Kark et al., 2015). Another aspect is that species listings often follow human development. Areas not experiencing significant anthropogenic impacts, e.g., Northern California or low population arid states like Nevada or Arizona will naturally field fewer conservation banks. Furthermore, conservation banks often rely on conservation easements between the landowner and the land trust. Funds often stem from federal, state, or local government, NGOs as well as private donations. Management and land-use restrictions of said land through a land trust with sufficient funds, experience, and clear goals, while the landowner can receive significant state and federal tax advantages, could be another reason for conservation banks being less likely to experience bottlenecks (e.g., Bayon et al., 2012; Fox & Nino-Murcia, 2005).

Our findings suggest that species banks do not adhere to any of the four bottlenecks due to their different operational approach and legislative framework. Imperiled species with a limited range and likely to be affected by climate and land-use change and ongoing urbanization could potentially lead to a rapid increase in newly established conservation banks on private land, considering that large proportions of endangered are indeed on private land (Clancy et al., 2020; Poudel et al., 2019). Risk reduction for investors and incentivization will be even more important in the future to target private land and developing ways to anticipate listings better, since species listings currently outpace bank establishment due to the reactive nature of conservation banks which would require a more proactive approach helping to anticipate future developments and listings better. (e.g., Clancy et al., 2020; Kerkvliet, 2021; Stein et al., 2008).

4.4. General considerations

Aside from YAC, UCA, and AUR, several key aspects should be considered for future banking practices. Future environmental and climate change stress will impact banks greatly both in terms of performance criteria as well as areas where mitigation might be needed. Plans to mandate climate change mitigation are ongoing and are likely to be part of future policies and banking requirements (e.g., Delgado et al. 2011; Latimer & Hill., 2007; WRI, 2022). With an increased demand for all four bank types, perceived and actual completion could increase while establishment and initiation costs are already high, increasing risk and uncertainty for current and prospective bank owners. Future banking practices and guidance needs to focus on assuring that conservation priorities align with feasibility and revenue expectations of owners while increasing transparency on said costs and reported data, which is still a persisting issue (e.g., Clancy et al., 2020; Kerkvliet, 2021; Poudel et al., 2019; Stein et al., 2008). RIBITS as a centralized database needs to be improved in terms of provided data as well as data clarity. Currently, only a certain proportion of banks has full reports associated with them, costs and investments are in most cases not accessible and area to credit or ecosystem service to credit conversions as well as initial impact type and extent are hard to trace which make difficult to determine if ecological equivalency was achieved. While RIBITS is an excellent data repository for broad banking characteristics, the more important in detail data that would warrant in detail guidance and potential policy changes is largely still unavailable.

5. Conclusions

Banking frameworks designed as offsetting mechanism alternatives, have become increasingly popular over the past 26 years, and will continue to do so according to the data as well as different organizations and countries aiming to establish banking as a widespread global mitigation mechanism (Santos et al., 2015). Land, usable for banks will potentially decrease in the future due to prime areas already being used as banks in combination with further land development in the conterminous United States (Fox & Nino-Murcia, 2005). Findings from our study conclude that based on past trends for supply and demand, mitigation banks targeting wetlands and multiple ecosystems could experience a *release bottleneck* given that demand seems to outpace credit release, while there are no indications for *demand* or *supply bottlenecks* based on newly established banks and credit withdrawal. Advance credit release through mitigation fee programs could help address this issue as well as expand the network to avoid *regional bottlenecks*, especially given future climate stress predictions (e.g., BenDor et al., 2013; Stephenson & Tutko, 2018; Vaissière et al., 2017; WRI, 2022). Advance credit release however needs to be handled carefully and, on a case-by-case basis with strong guidance and regulatory assurance that predicted benefits will be achieved by the bank while accounting for time-lags, a system that is not yet in place or developed enough (e.g., BenDor et al., 2013; Stephenson & Tutko, 2018; Vaissière et al., 2017). Stream mitigation banking is predicted to meet current and future demand, with the main driver potentially being faster turnaround times due to large use of rehabilitation efforts, land-use planning, and stream mitigation banking being a younger practice compared to mitigation banking, becoming more popular in the mid-2000s. Future trends could be like wetlands mitigation and multi-ecosystem banking considering this time lag (BenDor & Riggsbee, 2011). Current mitigation banking capacities and reserves are focused heavily on the southeastern United States.

Future developments likely will see a shift in regionality to other areas which are not yet part of the banking network given predicted climate and land-use changes (Powers & Jetz, 2019). Conservation banks, targeting single and multiple species, do not seem to be experiencing bottlenecks in the same manner as mitigation banks, due to their demand mostly being driven by species listings and delisting's under the ESA, land development, and advantages of conservation easements. Future practice for conservation banks will be faced with issues of aligning financial feasibility for owners with ESA and FWS conservation goals. It will be vital to implement an increased number of transboundary agreements between countries, like the trilateral agreement for migratory birds between Canada, the United States, and Mexico to protect migratory and large-range species, to cover a wider variety of endangered species (Bunn et al., 2014; Kreye & Pienaar, 2015; Poudel et al., 2019).

Our results show that banking as an alternative offsetting mechanism is a well-established market within the United States. Past data and future predictions, as well as other literature, underline that banking is still facing issues of how to implement and enforce ecological performance criteria into banking agreements while tackling shortcomings of ecological sciences to design sound and feasible criteria and ecosystem benefits to credit transactions (e.g., Robertson, 2004; Wende et al., 2005). Furthermore, our results and case study examples show the difficulties in aligning different stakeholder interests while considering different spatial scales of regulations, laws, and policies within the boundaries of a market ecosystem that introduces aspects like competition, credit prices, and risk assessments by investors (e.g., Robertson, 2004; Wende et al., 2005). These general issues stand opposed to the benefits of the third-party nature of banks, long-term management requirements, fostering of ecosystem stewardship by private owners, and incorporation of large-scale habitat preservation and across-border agreements.

Availability of data and material

Data is available through the Regulatory In-lieu Fee and Bank Information Tracking System (RIBITS) - https://ribits.ops.usace.army.mil/ and figshare: https://doi.org/10.6084/m9.figshare.15911949.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jnc.2022.126159.

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