Atlantic States Marine Fisheries Commission

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Atlantic Menhaden Stock Assessment Subcommittee (SAS) and Ecological Reference Point Workgroup (ERP) Call Summary

April 13, 2023

Committee Members in Attendance: Matt Cieri (ERP Chair), Sydney Alhale, Jeff Brust, Brooke Lowman, Jason McNamee, Alexei Sharov, Jason Boucher, Mike Celestino, David Chagaris, Micah Dean, Shanna Madsen, Howard Townsend

ASMFC Staff: James Boyle (ISFMP), Kristen Anstead (Science), Katie Drew (Science)

Public: Genny Nesslage, Margaret Conroy, Keilin Gamboa-Salazar, Max Appelman, Allison Colden, Jeff Kaelin, Tom Lilly, Shaun Gehan, Peter Himchak

Major Decisions

- The SAS approved the proposal to change the 2025 single-species assessment from a benchmark to an update

Next Steps

- Staff will circulate doodle polls for the May and October workshops and Terms of Reference for the single-species update and ERP benchmark

Discussion Summary

Assessment Schedule and Single-Species Update Proposal

Recently, ASMFC staff discussed the unusually busy stock assessment schedule for 2023-2025 and made suggestions for where work could be decreased. One of the suggestions was changing the 2025 single-species benchmark assessment to an update and Kristen presented this option to the SAS. The reasoning behind this suggestion was that the Beaufort Assessment Model (BAM) is a mature assessment tool that has been peer reviewed for menhaden several times (e.g., 2011, 2015, 2020). Since there are no planned changes to the model structure or inputs for 2025, changing the single-species assessment to an update would reduce the workload for Technical Committee (TC), SAS, and peer review (PR) panel members. Kristen outlined that within the update framework, the SAS can still investigate the MARECO index for inclusion in the BAM since it was included in the 2020 benchmark, discuss spatial considerations for BAM as potential paths forward for the 2031 benchmark assessment, further investigate the odd behavior of the terminal year of BAM observed in the last two assessments, and make research recommendations for 2031. Additionally, the SAS can still consider if the number of age and length samples collected from different commercial gears and regions is sufficient to characterize the fishery and discuss retrospective adjustments for projections.

SAS members expressed concern about how to proceed if the BAM update encounters problems that can only be addressed through a benchmark, incorporating any new data sources that address past research recommendations, and the optics of not doing a benchmark for such a high-profile species. Staff reiterated that the framework is already in place if a benchmark is needed part-way through (e.g., SAS and Terms of Reference have already been approved by the Board, peer review is already on the SEDAR schedule) and while it would not be ideal, flexibility is built into the schedule already since ERP is going through a benchmark. Additionally, research recommendations were recently reviewed during the 2022 stock assessment update and there were no significant projects noted that would fundamentally change BAM or its inputs. There are also advantages to having the PR focus on the ERP assessment, from an optics perspective, since there was a lot of public support for moving to multi-species management for this species.

The SAS ultimately supported moving from a benchmark to an update for the 2025 assessment given that there are no proposed changes for the model structure or inputs. If that change is accepted by the Assessment Science Committee and the Policy Board, the timeline for the update will be the same as what was proposed for the benchmark except the single-species assessment may need less time to meet during the proposed workshops (Table 1).

ERP Terms of Reference

The ERP WG reviewed the ERP TORs to evaluate whether they needed to be modified due to the proposed change from a benchmark to an update for the single-species assessment. The WG agreed that the TORs as modified on the previous call were still suitable, and only recommended removing the word “benchmark” when referring to the single-species assessment. The modified version will be circulated with the meeting summary and sent to the Board for approval at the May meeting.

ERP Methods and Data Workshop Planning

Katie reviewed the goals and major topics of the upcoming Methods Workshop I, which will be an ERP-only meeting. The workshop will be held via webinar, in order to maximize participation while keeping the assessment moving forward. The ERP WG will review the models explored during the previous benchmark assessment and discuss which ones to develop further moving forward, as well as discussing new analyses or models that could be developed for the 2025 benchmark. The WG will also identify the data needs to support the proposed models to best tailor the 2023 data submission request. Lead modelers for the suite of models explored in the previous benchmark will provide a brief overview of their respective models and comment on whether and/or how the model should be developed further for the 2025 benchmark. The workshop will need approximately 2 days of discussion, but that may be spread out over 2-4 days, depending on WG member availability and other scheduling considerations.

In addition, ASMFC will put out a call for data and models to external researchers and stakeholders via press release prior to the workshop, as is done for every benchmark assessment. People who are interested in submitting data or models can provide a “pre-proposal” type description of the dataset or model for the ERP WG to consider at the May workshop, and if the WG is interested in pursuing that submission further, the raw data or the detailed model description and code will be requested for the October meeting.

Some SAS members expressed concern that this meeting will be in webinar format instead of in-person, as they felt in-person workshops would better facilitate the kind of wide-ranging, conceptual discussion needed for these topics. Staff appreciated these concerns, but noted that there was not enough time to organize an in-person meeting in May and that pushing the meeting back further into the summer would reduce attendance of ERP WG members who had previous commitments. However, the October Data Workshop will be an in-person workshop, and because the single-species assessment will no longer need time at that workshop, there will be time to continue the discussion started at the May webinar-based workshop. Katie noted that the workshop structure was a little different from the usual ASMFC benchmark process because of the unique needs of the ERP assessment, and that the Methods Workshop I could be considered more of a Methods Scoping Workshop, where models will be initially considered for inclusion or exclusion, and final decisions on the scope of work for the benchmark will not be made until the in-person October meeting, which would be more of a Data and Methods Workshop.

Public Comment

Allison Colden (Chesapeake Bay Foundation) raised concerns about recent changes in the age composition of the catch and asked whether that would be considered during the 2025 assessment. Kristen noted that the bait and reduction catch-at-age data will be updated and examined for the single-species assessment, so observed changes will be incorporated into those results. Matt noted that the single-species update results with those data will be included in the ERP model, but the extent to which changes in the age-structure will be propagated through depends on the structure each ERP model.

Tom Lilly raised similar concerns about changes in the age structure of the reduction fishery and the implications for maturity and fecundity in the Bay and asked whether the data from the state bait samples sent to Beaufort for ageing were being sent back to the states. Kristen noted that age data were sent back to the states upon request and were fully provided to ASMFC for assessment updates. He also noted the poor reproductive condition of both striped bass and osprey in the Bay and connected that to the menhaden fishery. He urged the ERP WG to consider whether additional modeling or research was really needed to establish more conservative catch limits for the Chesapeake Bay.

In light of the public comment about age data, Matt reminded the group that there will be a menhaden ageing workshop in November. The objective of the workshop is to standardize ageing protocols between the states and the Beaufort lab to allow the states to take over the ageing of the bait samples instead of having Beaufort being responsible for all ages.

Table 1. Proposed timeline of the 2025 single-species and ERP assessments.

	Milestone	Date
✔	TC Call to review TORs and timeline	Oct. 4, 2022
✔	TC/ERP WG planning call	Feb. 24, 2023
	SAS/ERP WG planning call	April 13, 2023
	Methods Scoping Workshop (ERP)	**May 2023**
	New dataset submissions (ERPs)	**June 2023**
	Data and Methods Workshop (ERP)	**October 2023**
	2022-2023 Menhaden FI data submitted	February 2024
	2022-2023 Menhaden FD data submitted	April 2024
	2022-2023 Multispecies data submitted	July/Aug 2024
	Methods Workshop II	**October 2024**
	Assessment Workshop	**February 2025**
	Report Components to Staff	May 16, 2025
	Final report to SAS/ERP WG	June 2, 2025
	SAS/ERP WG call to approve report for TC review	Week of June 16, 2025
	Reports to TC/ERP WG for review	June 30, 2025
	TC call to approve reports	**Week of July 14, 2025**
	Reports to review panel	August 1, 2025
	Peer Review Workshop	**mid-late August 2025**
	Reports to Board (Meeting Materials)	Oct. 2, 2025
	Assessments presented at Annual Meeting	Oct. 16-20, 2025

From: lee Ceperich
To: Tina Berger; James Boyle; Katie Drew
Subject: [External] ASMFC Menhaden Board May 1st comments
Date: Tuesday, April 25, 2023 2:25:50 PM

Dear ASMFC board members,

Thank you for your continued work to manage and protect our marine resources. Please focus your efforts on behalf of VA, as the issue of overfishing of menhaden in the Chesapeake Bay is unsustainable. It appears that VA's own state government/ VMRC are unable or unwilling to address the issue effectively due to economic and political reasons. I would assume that MD is also being adversely affected by the overfishing of the Bay but I'm writing today on behalf of VA as a resident of the Northern Neck area who has witnessed the adverse effects of industrial fishing in the Bay on wildlife and residents directly.

As you know, VMRC has succeeded in getting an MOA with Omega Protein to limit fishing during holiday weekends and near the Chesapeake Bay Bridge Tunnel. This development is a step in the right direction and will limit the possibility of continued public relations problems brought on by fish spills on public beaches during peak tourist weekends, and will also reduce conflict in busy recreational fishing areas. However, the MOA will do little to address the larger problem which is continued LOCALIZED overfishing in a concentrated area. I understand that the data supports the fact that menhaden is not overfished on the East Coast in general. Have the ERPs used to measure the general population of menhaden been applied to the Chesapeake Bay region specifically?

Please explain how taking 80% of the East Coast quota of menhaden from one small area off of the Virginia coastline in the Chesapeake Bay is equitable or sustainable for the local wildlife populations -predator fish species (Striped bass, bluefish) birds (osprey) or for the other users of the bay-commercial fisherman, residents, small businesses, tourists, recreational fisherman. Why are all other stakeholders that rely on a healthy Bay ecosystem disregarded in favor of the interests of one foreign company's profit margin and employment of 250 individuals in

Reedville?

I sincerely don't understand how the commissions and individuals responsible for regulating the fishery (state government, VMRC, and ASMFC) can allow this imbalance of use in one area to take place. It is just common sense that if all the forage is taken from one area that the wildlife dependent on that forage species in that area will suffer.

ASMFC's own report to the Secretary of Commerce in 2019 from Bob Beal stated that "even with the stock of Atlantic menhaden not undergoing overfishing on a coastwide basis, localized depletion within the unique Bay ecosystem could have serious adverse effects on bay commission managed fisheries in poor condition, as well as other avian and aquatic species" Currently bay indicator species such as striped bass and ospreys are suffering chronic reproductive failure according to published sources, and local decreases in populations support these statements.

VA Code 28-203 that applies to menhaden allocations specifically states that the social and economic consequences must be considered in management of the fishery. Section 6 of ASMFC Charter and menhaden Amendment 3 also states that social and economic consequences must be considered. Instead, the VA quota was recently raised by 22,000 and Ocean Harvesters (for Omega) has added another ship to their fleet.

It is indisputable that the commercial fishing operation is important for the VA and local economy, but the small businesses that rely on recreational and commercial fishing, tourism and the overriding importance of protecting the Bay for future generations must be equally considered. Everyone must work together to identify a compromise solution that serves to protect the Bay ecosystem for future generations, and satisfy competing financial interests of the reduction fishery operation and other businesses/users that rely on a healthy Bay.

If Omega Protein is going to be allowed to continue operations, why can't the industrial fishing operation be restricted to the US Atlantic Zone? Why does VA allow factory fishing operations to occur so close to shore? No other state on the East Coast permits industrial fishing of this scale in their state waters.

As a Virginia resident I respectfully ask the board to consider the current state of affairs in the Bay and to take immediate and decisive action to manage this crucial issue.

Best regards,

Lee Ceperich
White Stone, VA

From:	Alan Kippy
To:	Tina Berger
Subject:	[External] FW: ASMFC Menhaden Board May 1st comments
Date:	Tuesday, April 25, 2023 11:50:37 AM

Subject: RE: ASMFC Menhaden Board May 1st comments

I have been in the Ches. Bay area since 1985. My first trip to the Bay allowed me to witness dozens of acres of full size adult bunker and 8 to 15 pound bluefish slaughtering them under the birds EVERYWHERE I looked. I also caught grey trout to 14 pounds every spring (early June) in Delaware Bay (Brandywine shoals)at night. Fish and bunker were plentiful then. Now….just ribbonfish. The big blues have been history for a long time in the bay. They follow the bunker….no bunker – no blues. I hear they are out 35 miles or more. I don't know. Grey trout are all but gone, but in the 90's you could catch hundreds of them under the lights at Kiptopeake. Not now! Herring? WTF happened to the herring? Mixed right along with the bunker I'd assume, turned into fish oil. No finger pointing there and I am surprised about that. People eat herring too!

You and your followers MUST totally shut down the bunker fleet here in the bay. Send them back to Canada and let em net yellow perch or something, before they deplete everything but ribbonfish here. I heard that OMEGA does not allow 'observers' from fed or state to be aboard their vessels. Is that correct? They have more power than our state and fed. Wildlife folks? That needs to change too. THEY must be shown that they are here by our graces and subject to our laws and limits. They gave us the bird finger when they intentionally overharvested bunker not long ago. Problem is……THEY'RE STILL HERE!!! Move em outta here please for our future's sake!!!

Alan Cochran

4122 Bruning Ct.

Fairfax, VA 22032

From: Tom Lilly <foragematters@aol.com>
Sent: Tuesday, April 25, 2023 8:53 AM
To: Tom Lilly <foragematters@aol.com>
Cc: jjbello@att.net; steveatkinson52@verizon.net; fayebailey28@gmail.com; bel44@verizon.net; debbiescampbell@icloud.com; lceperich@gmail.com; jcoker@co.northampton.va.us; daphnekcole8248@gmail.com; wdemmerle@outlook.com; cdollarchesapeake@gmail.com; hafbrau1@aol.com; info@puppydrum.net; jhiggins@trcp.org; jerrycole@gmail.com; mwrightjohnson@gmail.com; david_kabler@hotmail.com; sophieandfolly@yahoo.com; bkersta@aol.com; alankippy@gmail.com; mleonard@asafishing.org; almckegg@gmail.com; cmedice10@gmail.com; cmoore@cbf.org; savoystudio@gmail.com; chad@mraa.com; chris@bayflyfishing.com; RPaxton@dgparchitects.com; jbr1948@comcast.net; jerogers@aol.com; rogard@yahoo.com; branshew@gmail.com; davidsikorski@ccamd.org; l.lobosky@gmail.com; katturk1@gmail.com; blueyedmermaid@gmail.com; wvonohlen@gmail.com; kate.wilke@TNC.com; flypax@md.metrocast.net; dunnsville@gmail.com; llehowicz@gmail.com; eslaughter8890@gmail.com; grethelindemann@aol.com; cathlukas@gmail.com; cfoconsultllc@gmail.com
Subject: ASMFC Menhaden Board May 1st comments

To the above interested in VA menhaden conservation

Thank you for writing to the VMRC about the proposed buff/bycatch regulations. I secured copies by a FOIA request, I wanted to alert you to an ASMFC menhaden board meeting where Chair Mel Bell of SC has asked the VA delegates to report to the board on VA menhaden management. Certainly they will be telling the board about the MOA with the purse seine bait and reduction fishing and that menhaden are not overfished do everything is AOK in Virginia.

From out point of view VA menhaden management by the VMRC is not OK, quite the opposite. This begins when the MRC staff Shanna Masden and Pat Geer keep telling the MRC that the ASMFC says menhaden are not overfished, the stock is very healthy, This is the same thing Ben Landry of Omega keeps repeating. I hate to use the word "lie" but ASMFC Director Bob Beal addressed this in his letter to Commerce Secretary Ross in 2019, at page 3, "The Commissions action in setting the cap at 51,000mt .....reflects the reality that even with the stock of Atlantic menhaden not undergoing fishing on a coastwide basis, localizes depletion within the unique Bar ecosystem could have serious adverse effects on bay Commission managed fisheries in poor condition, as well as other avian and aquatic species" (scan) In fact , bay wildlife , particularly or two key menhaden overharvesting "indicator species" are suffering chronic reproductive failure. The striped bass spawning stock has four years of the lowest young of the year ever (scan) and ospreys are in a bay wide dye off from chick starvation due to menhaden harvesting (scan- Frontier's Journal- Academia.

The VMRC is aware the ASMFC finally adopted menhaden specific environmental reference points in 2020 but they are not being made aware of the conclusion that striped bass are the most "sensitive " fish species to menhaden harvests (scan Press Release) they are the "canary in the coal mine according to the ASMFC (scan) This is the science that connects the dots ....where there is overharvesting the indicator species will be harmed first and worst and the two species are having the worst harm a species can have,,,,reproductive failure. Ospreys are the second indicator species and they are in failure mode as well. One failure corroborates the other as to primary cause,

We now know the MRC has never gathered the information necessary to comply with VA Code 28-203 that applies to menhaden allocations (scan) That law requires the favor " the Commonwealth, the food and recreational fishermen " .We learned this in the VMRC response to our FOIA requests #23-24 (scan), In addition to Code section 28-203 the Commission Charter and menhaden Amendment 3 (which the US Department of Commerce forced Virginia to comply with) say allocations must consider not only the ecological consequences but also the social and economic consequences. The social and economic consequences of the decline in striped bass fishing in Virginia are grave indeed For example 600,000 fewer trips a year and $ 150,000 less spent at VA businesses a year by striped bass fiahermen. (scan VA data) Participation salt water fishing 15 million trips a year VA and MD (

scan NOAA- Lovell)

This has gone on too long but...We know why the MRC staff and the Commissioners refuse to listen to or apply available socio-economic information---its very obvious why they don't. Improving striped bass fishing by stopping the overharvestig as the ERP directs and the Frontier article confirm could save the ospreys creates benefits to the people, the fishermen and their children , to the charter captains and food fishermen in the ratios of a thousand to one . Marinas a ratio of one to eight hundred. Omega captains vs charter and food fish "captains" 10 to 1,800 in VA and MD, commercial crews , VA purse seiners (estimate 150) so 150 to 3,777 MD VA crews, 150 " purse seine fishermen vs 600,000 recreational fishermen MD and VA and about 50,000 of them children, charter clients benefited in VA and Md about 400,000 a year, about 90 fish wholesalers in the two states, one foreign owned business vs at least 10,000 small businesses in the two states affected by salt water fishing and boating, use of about 10 purse seine ships but decreased use and value of about 100,000 recreational fishing boats on the bay where these boats are often a families second most expensive investment and probably its most expensive one to own with insurance, fuel, repairs, trailer expense, replacement motors and electronics, slip fees, licensing fees and a hundred other expenses spent in MD and VA, THere is another thing here ..all the friendship and experiences that we have in those 15 million days fishing a year and all the proven mental and physical health benefits of nature based recreation specially for children (scan physical-health benefits)

It is not just at the VMRC that the managers refuse to consider any of the things I just mentioned. The menhaden delegates at the ASMFC totally refuse to comply with Section 6 of their Charter and menhaden Amendment 3 that says social and economic consequence MUST be considered. There was an important board meeting on November 22, 2022 there the delegates rained the Atlantic TAC (Commercial Quota) from

I

Tina Berger

From: Tom Lilly <foragematters@aol.com>
Sent: Friday, April 21, 2023 3:58 PM
To: James Boyle; Katie Drew; Robert Beal; Tina Berger
Subject: [External] Meeting May 1st menhaden possibilities
Attachments: NOAA Aging.pdf; YOY DNR.pdf; Canary story.pdf; Frontiers 2023.pdf; Frontiers 2019.pdf; ERP Press.pdf

To ASMFC Director Bob Beal , James Boyle,menhaden staff, scientists and Tina Berger (will send omitted scans later.....slo connection here)

Thought with the meeting on menhaden May 1st I should make you aware of some of the facts and opinions about Chesapeake Bay issues centering on overharvesting of menhaden causing reproductive failure of the bay's two iconic and menhaden "indicator" species, the striped bass spawning stock and ospreys. The ERP definitions and modeling bringing ospreys within the definion (see scans... ERP Press Release and Canary documents and "Path"article 2021 in "Frontiers" (scan) say plainly that severe problems such as reproductive failure (a species worst problem) in striped bass and ospreys is due to overharvesting of menhaden.The osprey article , also in Frontiers, (scan) corroborates what Dr Bryan Watts has been saying for years and in a real world sense both failures of these the two key avian and predator fish key species that represent the health of the Chesapeake Bay lays on a second layer of proof of cause. Both have failed.

With this proof of cause and effect and with the overwhelming evidence of negative social and economic consequences (scan Phil paper) compared to (scan George NY) these seem to be several relevant topics for discussion at the May 1st meeting. They are described below. There are also suggested motions.

Could you share this with your delegates so they can decide if it would be in the best interests of all the states and in particular Maryland that outlawed factory fishing 70 years ago but cannot prevent what you are allowing in Virginia. I will of course be available for any back up information, scans or discussion you want. The politics of this in Virginia are going to prevent any progress there ...the Governor has packed the MRC with Reedville - Omega advocates...any relief for Maryland will have to come from other states at the ASMFC for the benefit of everyone. Thanks again Tom Lilly 443 235 4465

Since menhaden board chair Mel Bell has scheduled VA menhaden as an item for discussion at the May 1st hybrid meeting I thought I would touch base with you. From what has gone on in VA the last two years it seems unlikely the VMRC will respond to anything or anyone interested in change in the menhaden harvest there.

That leaves the ASMFC to consider changes in Virginia such as reducing the current 51,000 mt cap, applying the cap to the VA coast or just zoning the reduction fishing into the US Atlantic. Since MD DNR in its statement on Resolution 02 questioned the authority of the ASMFC to do this I spoke to Bob Beal who was good enough to answer in the below mail . He reminded me that the only jurisdiction the states have through the Commission is to regulate in the states.(DNR 02 Statement-scan)

I join with millions of Marylanders and a bay full of precious wildlife that could benefit if you would ask the menhaden board to finally consider this proposal

" Determine the ecologic, social and economic consequences of leaving the factory fishing where it is or moving it out of the Bay or into the US Atlantic zone" (based on the best available information)

Since we know the Bay's two "indicator species" for menhaden overharvesting are suffering chronic reproductive failure (n.1) and that by the ERP definitions this failure of the striped bass spawning stock and nesting ospreys in due to overharvesting (n.2). The negative consequences of this to Marylanders (n.3) and Virginians (n.4) is all too well known. So another way to get this issue before the board could be a motion as follows:

"That the board determine the primary and contributing causes of the reproductive problems in the striped bass spawning stock and nesting ospreys in Chesapeake Bay based on the available scientific information and determine the likely social and economic consequences this has caused in Chesapeake Bay and determine the available management actions to correct the situation"

Another matter Allison mentioned at last weeks ASMFC ERP workshop was the percentage ot the year 0-2 menhaden harvested in the Bay. Allison said this size fish is most valuable for forage. Please look at the 2019-21 reduction fishing aging data finally coming out of the Beaufort lab. (scan). The Reduction catch of 0-2 year fish is in the Bay 99.1% . So in addition to the forage base and age diversity of the stock being destroyed there are many other bad consequences of this ...fish not allowed to spawn once, satisfying quota with large numbers of immature small fish etc. Another motion could be:

"That the board determine the cause and effect of the reduction industry harvesting large quantities of age 0-2 menhaden in Chesapeake Bay and the remedial measures that could be used to prevent or mitigate this in the future based on the best information now available

In conclusion and referring to the 15 million days Virginians and Marylanders, friends, families and children (and grandchildren) spend together salt water fishing a year (n.4) what is better to fill the holds of some multi millionaire's ships with thousands of tons of precious food that could be feeding our struggling wildlife or to leave it in the water to create more smiles on the faces of the kids and parents when they bring home some great memories of those adventures together and some fresh Chesapeake bay seafood to enjoy. That is the choice you make at every menhaden board meeting. Thanks for listening and I hope we can discuss this further before the meeting Tom Lilly 443 235 4465

SCANS:
(n.1) MD YOY
(n.2) ASMFC ERP Press Release
ASMFC "canary in coal mine"
as to the ERP definition and osprey
reproductive failure see article
scanned from Frontiers in Sci. journal
(n.3) PHIL's Charts MD data :
(n.4) Mail to VMRC re social and economics
10/24/22 at TLL mail VMRC

-----Original Message-----
From: Robert Beal <Rbeal@asmfc.org>
To: THOMAS LILLY <foragematters@aol.com>
Sent: Tue, Apr 18, 2023 4:16 pm
Subject: RE: [External] ASMFC Jurisdiction in state waters

Tom,

This is a follow-up to our conversation and your question regarding the Atlantic State Marine Fisheries Commission's ability to establish and require implementation of fisheries regulations in state waters. The Commission's role is to bring the states together to have them establish management programs for 27 species (or species groups) of marine fish or shellfish. Once the states approve these programs through the Commission process, they are obligated to implement the regulations consistent with the interstate fishery management plan. These regulations implemented by the states are binding in state waters.

The Commission is not a regulatory agency. It does not have the authority to implement regulations. However, as required by the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) the Commission's management plans must be implemented by the states.

Please let me know if you need more information on the Commission's process and authority,

Bob

From: Tom Lilly <foragematters@aol.com>
Sent: Tuesday, April 18, 2023 10:25 AM
To: Robert Beal <Rbeal@asmfc.org>
Subject: [External] ASMFC Jurisdiction in state waters

Hi Bob

Just a follow up on this. Could you write a response to this concern and address it to the menhaden board, to Mel Bell or to one of the staff concerned with menhaden or whomever is appropriate ?

Thanks Tom Lilly 443 235 4465

-----Original Message-----
From: Robert Beal <Rbeal@asmfc.org>
To: THOMAS LILLY <foragematters@aol.com>
Sent: Tue, Apr 11, 2023

Hi Tom,

I will give you a call at 2:30 tomorrow.

Bob

From: Tom Lilly <foragematters@aol.com>
Sent: Tuesday, April 11, 2023 12:23 PM
To: Robert Beal <Rbeal@asmfc.org>
Subject: Re: [External] Jurisdiction in state waters

From: Tom Lilly <foragematters@aol.com>
Sent: Tuesday, April 4, 2023 10:52 AM
To: Robert Beal <Rbeal@asmfc.org>
Subject: [External] Jurisdiction in state waters

Bob I know you are busy with things other than menhaden. Over the years I have heard and see comments that question the authority of the Commission to regulate seasons, gear, quotas and zones of fishing in state waters. As to Chesapeake bay and Virginia the bay cap has been in effect for over 15 years and, of course, was upheld by the US Commerce Department after Virginia challenged it. This, I believe, is one of many examples of the Commission's authority to act in State waters.

Could you possibly set aside a few minutes to discuss this ? Thanks Tom Lilly 443 235 4465

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REVIEW article

Front. Mar. Sci., 07 May 2021 | https://doi.org/10.3389/fmars.2021.607657 (https://doi.org/10.3389/fmars.2021.607657)

Check for updates

The Path to an Ecosystem Approach for Forage Fish Management: A Case Study of Atlantic Menhaden

Kristen A. Anstead (https://www.frontiersin.org/people/u/1089781)[1]*, Katie Drew (https://www.frontiersin.org/people/u/990320)[1], David Chagaris (https://www.frontiersin.org/people/u/495125)[2], Amy M. Schueller (https://www.frontiersin.org/people/u/1119106)[4], Jason E. McNamee (https://www.frontiersin.org/people/u/1124192)[5], Andre Buchheister (https://www.frontiersin.org/people/u/1120381)[6], Geneviève Nesslage (https://www.frontiersin.org/people/u/1126723)[7], Jim H. Uphoff Jr. (https://www.frontiersin.org/people/u/1171712)[8], Michael J. Wilberg (https://www.frontiersin.org/people/u/344791)[7], Alexei Sharov[9], Micah J. Dean[10], Jeffrey Brust[11], Michael Celestino[11], Shanna Madsen[12], Sarah Murray (https://www.frontiersin.org/people/u/1090785)[1], Max Appelman[1], Joseph C. Ballenger (https://www.frontiersin.org/people/u/1146004)[13], Joana Brito (https://www.frontiersin.org/people/u/359070)[2,14], Ellen Cosby[15], Caitlin Craig[16], Corrin Flora[17], Kurt Gottschall[18], Robert J. Latour (https://www.frontiersin.org/people/u/1146038)[19], Eddie Leonard[20], Ray Mroch[4], Josh Newhard (https://www.frontiersin.org/people/u/1111904)[21], Derek Orner[22], Chris Swanson[23], Jeff Tinsman[24], Edward D. Houde (https://www.frontiersin.org/people/u/615796)[7], Thomas J. Miller[7] and Howard Townsend (https://www.frontiersin.org/people/u/530527)[25]

https://www.frontiersin.org/artic

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[3]Maine Department of Natural Resources, Boothbay Harbor, ME, United States
[4]NOAA Fisheries, Beaufort, NC, United States
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from BAM. All focal species had recently undergone single-species stock assessments, which provided life history, landings, and index data through 2017, as well as estimates of fishing mortality and population size. Newer data were not available for all of the groups included in the full NWACS EwE model; as a result, inputs for those groups were extrapolated from the terminal year of 2013.

The ERP WG evaluated the five ERP models based on their performance (i.e., residuals, sensitivities, and other diagnostics), their strengths and weaknesses, and their ability to inform the fundamental ecosystem management objectives (Buchheister et al., 2017a,b; McNamee, 2018; Uphoff and Sharov, 2018; Nesslage and Wilberg, 2019; Chagaris et al., 2020). The ERP WG ultimately recommended using the NWACS-MICE model rather than the other four for two reasons. First, the EwE framework used by the NWACS-MICE model was the only approach that could address both the top-down effects of predation on Atlantic menhaden and the bottom-up effects of Atlantic menhaden on predator populations, which were required to evaluate the key tradeoffs between Atlantic menhaden harvest and predator needs that were central to the identified ecosystem objectives. Second, the NWACS-MICE implementation was less data-intensive than the full NWACS model, which reduced some of the uncertainty associated with modeling the data-poor predators and prey in the full model. This meant the NWACS-MICE model could be updated more quickly and efficiently, on a timeframe that met manager's needs. Comparisons of the full and MICE versions of the NWACS model indicated that the NWACS-MICE model included the fish predators most sensitive to the menhaden population. Striped bass was the most sensitive fish predator to Atlantic menhaden harvest in both models. In the full NWACS model, nearshore piscivorous birds were also sensitive to Atlantic menhaden *F*, but their response was similar to striped bass over the range of scenarios explored by the full model (Southeast Data Assessment and Review [SEDAR], 2020b). This choice was consistent with a growing body of literature that has recommended models of intermediate complexity (i.e., MICE) for ecosystems as representing a compromise between complexity/realism and uncertainty for use in management (Plagányi et al., 2014; Collie et al., 2016; Punt et al., 2016). Specifically, the ERP WG recommended using the NWACS-MICE in conjunction with the single-species assessment model, BAM; the NWACS-MICE model would provide strategic advice about the trade-offs between Atlantic menhaden fishing mortality and predator biomass to set reference points, while the single-species model would be used to provide short-term tactical advice about harvest strategies to achieve the ERP *F* target (Chagaris et al., 2020; Southeast Data Assessment and Review [SEDAR], 2020b). The ERP report was peer-reviewed with the single-species assessment in 2019, and the ERP WG's recommended tool was deemed acceptable for management use by a panel of independent experts (Southeast Data Assessment and Review [SEDAR], 2020b). The peer-review panel also recommended the continued development of the alternative models going forward.

Birds

Current Management

The development and implementation of ERPs for Atlantic menhaden was a lengthy process (Figure 4 and Table 1), but in August 2020, ASMFC adopted the approach from the ERP WG for management use. The ERP target was defined as the maximum *F* on Atlantic menhaden that would sustain striped bass at their biomass target when striped bass were fished at their *F* target. The ERP threshold was defined as the maximum *F* on Atlantic menhaden that would keep striped bass at its biomass threshold when striped bass was fished at its *F* target. For both reference points, all other species in the model were fished at their *status quo* (i.e., 2017) *F* rates. Striped bass was the focal predator species for this analysis because it was the most sensitive to Atlantic menhaden *F* in both the NWACS-MICE and the full NWACS models. Thus, levels of Atlantic menhaden *F* that sustain striped bass should also sustain piscivorous birds and less sensitive predators, in the absence of significant disruptions to the ecosystem (Southeast Data Assessment and Review [SEDAR], 2020b). With these ERP targets and thresholds, the Atlantic Menhaden Management Board reviewed projections from the single-species model, BAM, and set a quota for 2021 and 2022 of 194,400 mt, a 10% decrease in the quota from 2020.

Birds

FIGURE 4

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Food supplementation increases reproductive performance of ospreys in the lower Chesapeake Bay

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The Atlantic States Marine Fisheries Commission (ASMFC), the governing body responsible for managing fisheries on the U.S. East Coast, formally adopted the use of Ecological Reference Points (ERPs) for Atlantic menhaden, *Brevoortia tyrannus*. Scientists and stakeholders have long recognized the importance of menhaden and predators such as ospreys, *Pandion haliaetus*, that support the valuable ecotourism industry and hold cultural significance. Landings in the reduction fishery are at their lowest levels and menhaden is facing potential localized depletion. Mobjack Bay, located within the lower Chesapeake Bay, has been a focus of osprey research since 1970 and represents a barometer for the relationship between osprey breeding performance and the availability of their main prey, menhaden. Since local levels of menhaden abundance were not available, we conducted a supplemental menhaden feeding experiment on osprey pairs during the 2021 breeding season. Our main objective was to determine if the delivery rate of menhaden had an influence on nest success and productivity. Nest success ($\chi 2 = 5.5$, df = 1, P = 0.02) and productivity (β = 0.88, SE = 0.45, CI = 0.049, 1.825, P = 0.048) were significantly higher within the treatment group. Reproductive rates within the control group were low and unsustainable suggesting that current menhaden availability is too low to support a demographically stable osprey population. Menhaden populations should be maintained at levels that will sustain a stable osprey population in which they are able to produce 1.15 young/active nest to offset mortality.

KEYWORDS

osprey, *Pandion haliaetus*, menhaden, *Brevoortia tyrannus*, localized depletion, ecological reference points, food supplementation

1 Introduction

World fisheries landings since the late 1980s have been steadily declining (Pauly and Zeller, 2016, FAO, 2020). With mounting concern over the state of our fisheries, management strategies have shifted focus from single-species to ecosystem-based objectives (Pauly et al., 2008). This style of management attempts to integrate ecological, economic, and social factors to secure and protect the sustainability of our fisheries and the ecosystems within which they reside (Einoder, 2009). Thus, United States federal policy firmly reinforces the implementation of Ecosystem-Based Fisheries Management (EBFM) which is an approach that considers trophic interactions and aims to promote the health and resilience of the ecosystem (McLeod and Leslie, 2009; Link, 2010, NMFS (National Marine Fisheries Service), 2016). Apex predators are essential indicators within this management approach and may provide more sensitive measures of changing fish populations because of their dietary dependencies (Furness, 1982; Diamond and Devlin, 2003). Monitoring fish-eating bird populations may be both more cost effective and better suited to the problem of understanding fish populations within an ecosystem (Cairns, 1988). Bird metrics may play an increasing role in the assessment of prey availability, especially in areas where conventional fisheries data are insufficient (Cairns, 1988). Bird populations may serve as an early warning system for changes in fish populations that have ecosystem implications (Kabuta and Laane, 2003; Cury et al., 2005).

The Atlantic States Marine Fisheries Commission (ASMFC), the governing body responsible for managing fisheries on the U.S. East Coast, formally adopted the use of Ecological Reference Points (ERPs) for Atlantic menhaden, *Brevoortia tyrannus*. Historical estimates of menhaden were limited and the harvest effects did not produce sufficient information on important predator species. Therefore, the ASMFC developed an interest in establishing ERPs to set quotas and evaluate menhaden's status and role as a forage species (Drew et al., 2021). Scientists and stakeholders have long recognized the importance of predators, such as bottlenose dolphins, *Tursiops truncates*, and humpback whales, *Megaptera novaeanglia*, that support a valuable ecotourism industry and hold cultural significance (Gannon and Waples, 2004; Glass and Watts, 2009; Butler et al., 2010; Smith et al., 2015; Drew et al., 2021).

Atlantic menhaden are a schooling fish that can be found along nearshore coasts along the Atlantic Ocean from Nova Scotia, CAN, to Florida, USA and go through large age- and size-dependent seasonal migrations (Dryfoos et al., 1973; Nicholson, 1978; Liljestrand et al., 2019). As indeterminate spawners, adults are capable of spawning multiple times in a season and inhabit estuarine and coastal areas such as Chesapeake Bay (Ahrenholz, 1991, Southeast Data Assessment and Review [SEDAR], 2020). As juveniles, they spend their first spring and summer in estuaries and by late fall, they join with other subadults and adults and migrate to nearshore coastal waters (Southeast Data Assessment and Review [SEDAR], 2020; Anstead et al., 2021).

Menhaden support the largest fishery in the U.S. East Coast by volume and is used for bait and reduced to fish oil and meal which are used for animal feed, fertilizer, and human health supplements (Anstead et al., 2021). The reduction fishery began in the mid-1800s with the use of purse seine gear and peaked in 1956 with over 20 menhaden reduction factories along the Atlantic Coast (Southeast Data Assessment and Review [SEDAR], 2020). Currently, landings in the reduction fishery are at their lowest levels (Southeast Data Assessment and Review [SEDAR], 2020) and at Chesapeake Bay, populations of menhaden are facing potential localized depletion. ASMFC defined localized depletion in Chesapeake Bay "as a reduction in menhaden population density below the level of abundance that is sufficient to maintain its basic ecological, economic, and social/cultural functions" (Annis et al., 2009). Localized depletion has not been officially defined or evaluated by managers because estimates of the standing stock within Chesapeake Bay have been unavailable and thresholds for exploitation cannot be resolved.

Known as the fish hawk, we selected the osprey as an appropriate non-finfish ERP to evaluate localized depletion of menhaden and food limitation within Chesapeake Bay. The ERP Work Group emphasized the research need for diet data collection and demographic responses of non-finfish predators (Atlantic States Marine Fisheries Commission [ASMFC], 2017). According to Buccheister et al. (2017), the nearshore piscivorous birds such as ospreys are sensitive to the overfishing of menhaden. Ecologically, ospreys are generalized specialists (Beirregaard et al., 2014). Specialized in that they are obligate piscivores and generalized in that they predate upon many species of fish. Ospreys surface plunge at a maximum depth of one meter and are more susceptible to a decrease in fish density than other birds such as pursuit divers that search for prey while swimming on the water surface and dive to deeper depths (Ashmole, 1971; Cramp and Simmons, 1979). Piscivory and plunge diving influences an ecological indicator's response to fish supply perturbations (Einoder, 2009). Reduced prey availability and fluctuations in environmental conditions are more evident in the foraging behavior and breeding success of a specialist (Furness and Ainley, 1984; Montevecchi, 1993). Moreover, shallow divers and surface feeders are more vulnerable, are considered more sensitive indicators than pursuit divers, and show greater variation in breeding performance (Montevecchi, 1993, Monaghan et al., 1994; Scott et al., 2006). As one of the more recognized raptors, ospreys have been used as an ecotoxicological sentinel species of environmental health due to their reproductive responses to natural and anthropogenic pressures and life history traits (Henny et al., 2008; Johnson et al., 2008; Grove et al., 2009). Ospreys exhibit strong nest fidelity and their reproductive status is observable by ground, boat, or aerial surveys which makes them a valuable and efficient sentinel of the ecosystem (Ogden et al., 2014) and an appropriate ERP for menhaden (Buccheister et al., 2017).

The Chesapeake Bay supports one of the largest osprey breeding populations in the world (Henny, 1983; Watts and Paxton, 2007). As with many similar populations, ospreys in the Chesapeake Bay experienced dramatic declines in the post-World War II era due to reproductive suppression (Truitt, 1969; Kennedy, 1971; Wiemeyer, 1971; Reese, 1977) induced by environmental contaminants (Via, 1975; Wiemeyer et al., 1975). The population sustained a low point by 1973 when Henny et al. (1974) estimated its size to be 1,450 breeding pairs. From 1973 to 1995, the population more than doubled in size to nearly 3,500 pairs (Watts et al., 2004) and believed to be between 8,000-10,000 pairs in 2020. However, the population has experienced spatial variation in recovery (Watts et al., 2004; Watts and Paxton, 2007). For example, average doubling time for the population on low-salinity, upper reaches of tributaries, was less than four years while doubling time on higher-salinity reaches of the lower Chesapeake Bay exceeded 40 years (Watts et al., 2004). This variation reflects the extent of the earlier decline, immigration from other regions of the Chesapeake Bay, and the local demography of pairs that may have been influenced by prey availability.

Mobjack Bay has been a focus of osprey research since 1970 and represents a barometer for the relationship between osprey breeding performance and menhaden availability (Glass, 2008). During the mid-1970s, there was little evidence of food limitation reflected in osprey reproductive performance and brood sizes within the higher salinity zones of the lower Chesapeake Bay (Stinson, 1976). However by the early 2000s, the proportion of menhaden in the diet had dropped by 40% and reproductive rates had dropped to precarious levels (Glass, 2008). We conducted a supplemental feeding experiment for osprey pairs nesting in Mobjack Bay during the 2021 breeding season. A clear barrier in resolving the relationship between osprey productivity and menhaden consumption is the lack of menhaden abundance data that can be scaled down to the local level. If such data were available, we could monitor osprey foraging, provisioning, and productivity, and assess the functional response to available menhaden. Since such data are not available, a food manipulative experiment in the wild was performed (Piatt et al., 2007). Our secondary objective was to determine prey composition and the dietary importance of menhaden.

2 Methods

2.1 Study species

Ospreys are large, long-winged raptors with a nearly global distribution that feed exclusively on fish (Poole, 2019). Most osprey populations across North America are migratory, spend the winter months in Central or South America and begin breeding at the age of three (Henny & Wight, 1969) Age-at-first-reproduction in Chesapeake Bay ospreys was recorded from 4 years (Kinkead, 1985) to 5.7 years (Poole, 1989; Poole et al., 2002). As the population reaches carrying capacity, age-at-first-reproduction increases (Spitzer, 1980; Poole, 1989). Poole (1989) estimated that pairs within the Chesapeake Bay must produce 1.15 young per year in order to offset adult mortality. On average, if the population consistently meets or exceeds this rate (demographic source) then the population would be expected to be stable to increasing (Pulliam, 1988). If the reproductive rate consistently falls below this threshold (demographic sink) the population would be expected to decline in the absence of compensatory immigration.

2.2 Food addition experiment

We established treatment (fish addition) and control (no fish addition) nests to assess the effect of increased provisioning on demography. We added 472 g ± 7.9 (SE) of menhaden every 3.5d ± 0.2 to treatment nests from the time of hatching to six weeks of age. We delivered menhaden to nests using a telescopic pole with a mounted delivery device. We sourced fresh or previously frozen menhaden from a local fishing supply company and the fish were counted, weighed, coded, and separated into packages for easy deployment. We selected study nests based on accessibility and randomly assigned accessible nests to treatments. We conducted an initial survey (late March to mid-April) of the study area for osprey nests (N = 114) and recorded location (latitude, longitude), accessibility by boat, nesting stage, nest substrate, height over water, and water depth. We screened nests for initial inclusion in the study based on accessibility, height over water (to allow for ready access to the nest) and water depth (to allow for boat access and maneuverability). We only included nests within the study that survived to hatching stage. We monitored all nests included within the initial draw until clutches hatched. Nests that hatched eggs were randomly assigned to two treatment groups (Figure 1) including a control group (N = 15) and a food addition group (N = 16). The nests in the East River were limited in boat accessibility and therefore assigned to the control group.

2.3 Demography

We monitored nests twice per week from clutch completion to fledging to quantify demographic parameters including clutch size, brood size, and the number of young fledged. From observations, we determined brood reduction (number of young lost between hatching and fledging). We noted the age that nestlings died and the stage when nests failed. We consider a nest to be successful if the pair produced at least one young to fledging age. We consider productivity to be the number of young that reached fledging age (7 wks) per active nest (Steenhof and Newton, 2007). We used a telescopic mirror pole to facilitate the examination of nest contents for nests that were >2 m above the water line.

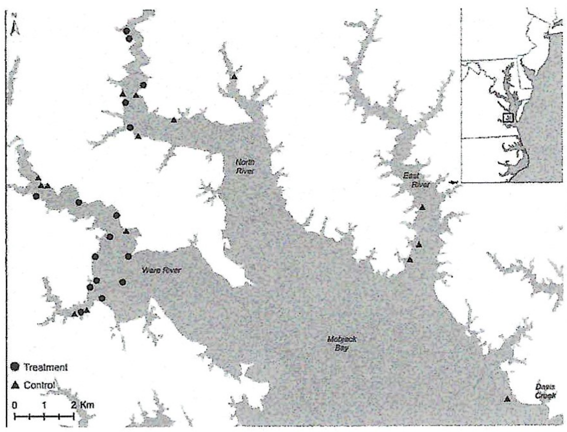

FIGURE 1
Map of the experimental area of Mobjack Bay on the lower eastern region of Chesapeake Bay, VA, USA. The locations of the control group (N = 15) represented by black triangles and the food addition group (N = 16) represented by black circles.

2.4 Provisioning

We used trail cams (Browning Strike Force HD Pro X - BTC-5HDPX) to quantify nest provisioning rates including the average number of fish (n/day), biomass (g/day) and energy (kcal/day) for a subsample of treatment (N = 7) and control (N = 4) nests. We deployed cameras on nest structures that would accommodate them. We fastened trail cams to 1.91 cm (3/4 inch) diameter conduit and mounted conduit to the nesting structure such that cameras were positioned approximately 1 m above the nest. Cameras were programmed to record an image every 5 min during daylight hours (05:00 to 22:00). We extracted images from the photo set that depicted fish delivered to nests and identified all fish to the lowest taxonomic level possible. Most fish were identified to the species level but others could only be identified to the genus or family level. We estimated fish length from photos within an image processing program, ImageJ with Java (https://imagej.nih.gov/ij/index.html) and compared to known lengths from reference structures (Poole et al., 2002) including adult bill (male =32.5, female = 34.6 mm) and talon (male = 28.9, female = 30.0 mm). We estimated the biomass (g) of each fish using species-specific length-mass equations from published literature and FishBase (https://fishbase.in/, Appendix 2). We converted biomass to energy (kcal) using published species-specific energy density values (Appendix 3). For species that could not be identified to species, we used length-mass equations and energy density from a representative species of the taxonomic group. We consider the provisioning of control nests to include fish provided by adults and for treatment nests to include fish provided by adults and menhaden that we added to nests. It is important to note that treatment nests that did not have trail cameras were observed by boat and consumption of supplemented fish by the adults and young were verified.

2.5 Statistical analysis

Data were not independent, not normally distributed, and non-homogenous therefore, we used appropriate tests. We investigated the influence of treatment (control vs food addition) on demographic parameters including nest success, clutch size, the number of young hatched, brood reduction, and productivity. We constructed a two-by-two contingency table and used Pearson's Chi-squared analysis to compare the relationship between treatment type and nest success. We used Generalized Linear Models (GLMs) to determine if there were the average differences in clutch size, the number of young hatched, brood reduction, and productivity between the treatment types. For provisioning (fish/d, biomass/d, energy content/d), we analyzed data from trail cameras to evaluate the relationship between provisioning and demographic parameters. It is important to note that our models were based on totals and/or average provisioning rates including naturally provisioned and supplemental fish.

We used Generalized Linear Mixed Models (GLMMs) with a negative binomial distribution and log link, nest and treatment type as the random effects, and food addition and total provisioning (natural and supplemented) as the fixed effects. For the influence of provisioning on demographics, we used GLMs with a negative binomial distribution and log link and compared the effects of the mean fish/d, biomass/d, and energy content/d (natural and supplemented) on productivity (both treatment groups combined, N = 11). We calculated the supplemented average biomass/d/nest and energy content/d/nest threshold needed for the production of 1.15 fledglings per nest-season (estimated break-even rate). All analyses were performed in RStudio 4.02 and we used the MASS and glmmTMB packages for model development and validated by the DHARMa package for residual diagnostics on hierarchical regression models (Venables and Ripley, 2002; Brooks et al., 2017; R Core Team, 2020; Hartig, 2021).

3 Results

3.1 Food addition and demography

For the food addition group, 13 of the 16 nests (81%) succeeded with an average productivity rate of 1.13 + 0.18 (SE) young/active nest. The three nests that failed in this group failed on average during the first 1.38 + 0.5 wks. or when young were 10 d old. For the control group, five of the 15 nests (33%) succeeded with an average productivity rate of 0.47 young/active nest. The ten nests that failed in this group failed on average during the first 2.2 + 0.5 wks. The age at failure (d) between the food addition and control groups was not statistically significantly different (β = -0.47, SE = 0.41, P = 0.25). The age at failure for the control group ranged from 3 - 42 d with the highest mortality experienced during the first 15.5 d + 3.4 of the nestling period. Nest success and productivity were significantly different between the control and food addition groups (Table 1, Figure 2). Clutch size, the number of young hatched, and brood

TABLE 1 Two-way contingency table used for the Pearson's Chi-squared analysis that summarizes the relationship between treatment types and nest success during the 2021 osprey breeding season in the lower Chesapeake Bay, VA, USA ($\chi 2$ = 5.5, df = 1, P = 0.02).

TREATMENT	NEST SUCCESS (NESTS) SUCCESSFUL	FAILED	TOTAL
FISH ADDITION	13	3	16
CONTROL	5	10	15
TOTAL	18	13	31

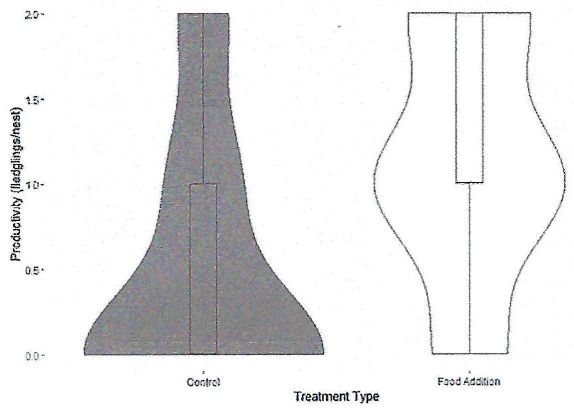

FIGURE 2
Productivity between the control group (N = 15) and the treatment group (N = 16) of ospreys during the 2021 breeding season in the lower Chesapeake Bay, VA, USA (β = 0.88, SE = 0.45, pseudo R^2 " 0.14, CI =0.049, 1.825, P= 0.048). Violin shapes represent the density of data distribution and the middle horizonal line of the box plots represent the median values.

reduction were not significantly different between the control and food addition groups (Table 2).

3.2 Provisioning and productivity

Food supplementation had a significant influence on the number of fish and amount of energy available to osprey broods (Table 3). A total of 241 Atlantic menhaden was supplemented to the food addition group and contributed 32,384 g that represented an estimated 61,206 kcal. This increased the average total prey biomass and energy content within the food addition group to 226.5 g/d/nest and 396.2 kcal/d/nest. The average biomass that was delivered to the control group was 166.8 g/d/nest and the average energy content was 242.2 kcal/d/nest (Appendix 1). For the control group, adult osprey delivered an average of 1.2 fish/d/nest compared to 1.1 fish/d/nest for the supplemented group.

Food supplementation had a significant influence on the likelihood that pairs reached the threshold reproductive rate of 1.15 young/nest (Figure 3). The estimated average fish biomass and energetic content needed for a pair to produce the threshold reproductive rate was 202.7 g/d and 338.6 kcal/d respectively. Within the study area, pairs required supplementation of 63.4 g/d of menhaden or 121 kcal/d in order to reach the productivity threshold.

Diet composition included a diverse list of fish species (Appendix 1). A total of 600 fish were documented as prey by ospreys in which 81% of taxa were identified to 21 species or to at least family. Atlantic menhaden (39%) dominated prey composition. Other known species included Atlantic herring (*Clupea harengus*) (10.3%), Atlantic croaker (*Micropogonias undulatus*) (5.8%), gizzard shad (*Dorosoma cepedianum*) (5.7%), and spot (*Leiostomus xanthurus*) (5%).

TABLE 2 Results for GLMs used to compare demographic parameters between treatment types during the 2021 osprey breeding season in the lower Chesapeake Bay, VA, USA.

DEMOGRAPHIC PARAMETERS	β	SE	PSEUDO r^2	CI	P
CLUTCH SIZE	0.07	0.21	0.75	-0.34, 0.48	0.75
No. of YOUNG HATCHED	0.12	0.24	0.04	-0.33, 0.62	0.57
BROOD REDUCTION	0.20	0.31	0.02	-0.81, 0.40	0.50

TABLE 3 Results of GLMMs with treatment effects on provisioning rates per d of nests under trail camera surveillance (N = 11) during the 2021 osprey breeding season in the lower Chesapeake Bay, VA, USA.

TREATMENT EFFECTS	β	SE	z VALUE	CI	P
FISH (number of fish/d)	0.25	0.02	13.4	0.21, 0.29	< 0.001
BIOMASS (g of fish/d)	0.002	0.0004	4.65	0.001, 0.003	< 0.001
ENERGY CONTENT (kcal of fish/d)	0.001	0.0002	5.22	0.008,0.002	< 0.001

4 Discussion

Supplementation of osprey nests with menhaden had a significant influence on the ability of nesting pairs to reach reproductive rates required for population maintenance. Our study shows that productivity was food limited as previous studies have substantiated (Simons and Martin, 1990; Richner, 1992; Wiehn and Korpimaki, 1997; Ferrer et al., 2018). Osprey pairs that did not receive supplementation had reproductive rates (0.47 young/nest) that were less than half of threshold levels. Within Mobjack Bay, productivity rates have shifted from reproductive surplus to reproductive deficit since the 1980s. For example, populations at various locations along the main stem of Chesapeake Bay were considered strongholds (McLean, 1986; Byrd, 1988). During 1983 and 1984, the average reproductive rate was 1.39 young/pair (Byrd, 1987). By 1988 and 1990, average productivity had dropped to 0.91 young/pair (Byrd, 1988, Byrd, 1990) and by 2005 and 2006 productivity had dropped further to 0.75 young/pair (Glass, 2008). If fishing pressure on menhaden within Chesapeake Bay persists, osprey productivity rates could decline precipitously, threaten population stability, and eventually lead to widespread population collapse. Menhaden populations should be maintained at levels that will sustain a stable osprey population in which they are able to produce 1.15 young/active nest to offset mortality.

Our research suggests that food addition significantly influenced osprey provisioning rates and these rates impacted reproductive performance. Specifically, daily average biomass and energy content of the prey composition significantly influenced productivity. Lind (1976) used a model developed by Wiens and Innis (1974) and calculated that each adult osprey required 286 kcal/d and each nestling at 11-16 d old needed at least 113 – 170 kcal/d. Based on calculations in which fish with an energy content of 1 kcal/g, a nest with two young plus the female would require 794 g of fish/d in order to successfully fledge and a nest with three young would require 1048 g of fish/d (Winberg, 1960). Along the U.S. Eastern Coast, Poole (1982) determined that male ospreys delivered 816 – 1426 g/d to nests that had young and nests that produced three – four young. In our study, menhaden consisted of 39% of the total diet composition and these fish have a high energy content of 1.89 kcal/g (June and Nicholson, 1964). Based on the calculations of Winberg (1960), if a nest fledged two young that was supplied with 39% or 309.7 g/d or 585.3 kcal/d of menhaden, the estimated additional biomass and energy content required would be 648.2 g/d or 1,225.1 kcal/d. Similarly if a nest fledged three young and was supplied with 39% or 408.7 g/d or 772.4 kcal/d of menhaden, the estimated additional biomass and energy content required would be 855.5 g/d or 1,616.9 kcal/d. For the nests in our study, the added average biomass and energetic threshold needed for a nest to reach the reproductive break-even point are 63.4 g/d and 121 kcal/d which would be a total average of 208.1 g/d and 347.6 kcal/d (Figure 3).

When we directly compared the provisioning rates in this study to historical studies in Mobjack Bay and the higher salinity areas of Chesapeake Bay, declines in daily fish deliveries were made evident. In 1975 and 1985, the fish delivery rate was 0.53 fish/hr/nest and 0.35 fish/hr/nest (McLean and Byrd, 1991). In 2006 and 2007, ospreys in the higher salinity areas delivered an average of 0.26 fish/h/nest (Glass, 2008). Our study revealed that in 2021, the fish delivery rate diminished to a mean of 0.11 fish/hr/nest. The average daily biomass delivered per nest fell from 237.1g and 172.3g in 1975 and 2007 to 144.7g in 2021 (Appendix 1, McLean and Byrd, 1991; Glass, 2008).

Brood reduction has been an effective parameter linking reproductive performance to food limitation in osprey (Glass, 2008). In a 5-yr study, Reese (1977) determined nestling loss rates in the upper Chesapeake Bay ranged from 8-23%. Nestling mortality rates were 47% and 78% for the supplementation and control groups respectively in this study. Poole (1984) conducted a

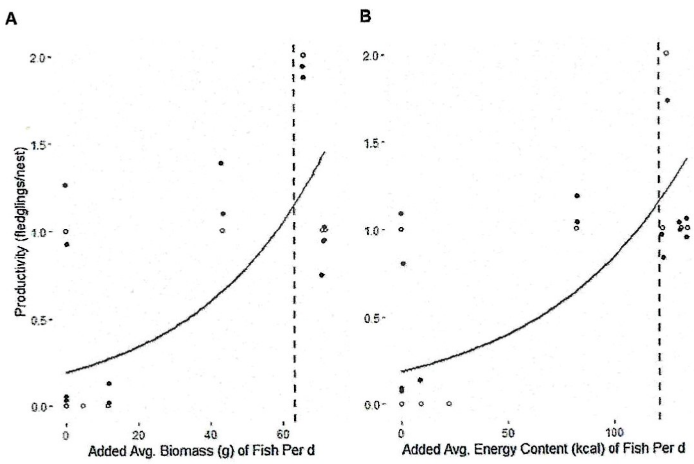

FIGURE 3
GLM's of the influence of the added (A) avg. biomass/d/nest (β = 0.03, SE = 0.01, Pseudo R^2 = 0.60, CI = 0.01, 0.05, P = 0.02) and (B) avg. energy content/d/nest (kcal) (β = 0.02, SE = 0.005, Pseudo R^2 = 0.64, CI = 0.006, 0.03, P = 0.02) for osprey pairs under trail camera surveillance after seven weeks post hatch of the first egg in 2021 breeding season in the lower Chesapeake Bay, VA, USA. The data points represented by white circles have been "jittered" along with random points represented in black circles for improved visibility of model fit. The dotted lines indicate the supplemented average biomass (63.4 g) and energy content (121 kcal) thresholds needed per d to produce 1.15 young per nest-season.

4-yr study in New England and determined that 75% of nestling mortality was caused by starvation. Glass and Watts (2009) determined that brood reduction was highly significant between nests in the lower estuarine sites compared to the higher estuarine sites and these data suggested that ospreys in the higher salinity areas were experiencing more food limitation than the lower salinity areas. Brood reduction has generally been linked with the lack of food availability in other study areas (Poole, 1982; Jamieson et al., 1983; Eriksson, 1986; Hagan, 1986; Forbes, 1991; Glass and Watts, 2009). Although brood reduction was higher in the control group, differences were not found to be significant in our study. This discrepancy could have been attributed to treatment effects in which the timing and intensity of the protocol was not strong enough to detect a significant signal. Perhaps if we supplemented more fish in greater frequency, we would have observed significant differences in the average brood reduction between the experimental groups.

The most compelling explanation for lower provisioning and productivity rates is localized depletion of the primary prey base. Although proximate causes of lower productivity may include storms, inter- and intraspecies competition, predation, as well as age-related care by parents, the ultimate cause of lower productivity may often be food shortage (Steenhof and Newton, 2007). Atlantic menhaden has a higher lipid content compared to other species with a nearly a 2:1 energy content/biomass ratio (June and Nicholson, 1964). Ospreys depend on menhaden and their reproductive performance is inextricably linked to the availability and abundance of this fish. In fact, previous studies have substantiated that menhaden are a vital prey item for ospreys during the breeding season particularly in the mid-Atlantic and northeastern United States (Spitzer and Poole, 1980; Poole, 1989; McLean and Byrd, 1991, Steidl et al., 1991, Glass and Watts, 2009). In 1985, this fish species consisted of 75% of the prey composition of ospreys in the lower Chesapeake Bay (McLean and Byrd, 1991). Then in 2006 and 2007, menhaden declined to 32% of the prey composition (Glass, 2008). In our study menhaden comprised of 39% of the total prey composition (Appendix 1). Assuming that the prey composition of ospreys reflects prey availability on a local level (Greene et al., 1983; Edwards, 1988; Glass, 2008), the current percentage of menhaden could indicate that this species has diminished in availability compared to the later portion of the 20th century.

Potential localized depletion of menhaden populations is one of the major sources of concern and conflict within Chesapeake Bay. According to the ASMFC, the coastwide stock assessment has determined that menhaden is not overfished and that no overfishing is occurring (Southeast Data Assessment and Review [SEDAR], 2020). However, a coastwide assessment does not capture spatial variation in menhaden availability for locations with persistent depletion such as Chesapeake Bay. Seine surveys of juvenile menhaden in Maryland and Virginia indicate that low levels of abundance and recruitment have been happening since the early 1990's and 2000's (Atlantic States Marine Fisheries Commission [ASMFC], 2004, Southeast Data Assessment and Review [SEDAR], 2020). Our data suggests that the reliable metric that links osprey population decline and food limitation is the osprey productivity rate. During the population decline in northern Florida, Bowman et al. (1989) determined that the productivity rate was 0.56 young/nest and this was due to insufficient food availability. When the Florida Bay population was healthy and food was abundant (Henny and Ogden, 1970), the productivity rate was 1.22 young/nest which is similar to the rate acquired by the food addition group of our study at 1.13 young/nest.

5 Conclusion

EBFM evolves when ERPs are consistently monitored (Pikitch et al., 2004). According to Amendment 3 of the Interstate Fishery Management Plan (FMP) for Atlantic menhaden (Southeast Data Assessment and Review [SEDAR], 2020; Anstead et al., 2021), ERPs are described as "a method to assess the status of menhaden not only with regard to the sustainability of human harvest, but also with the regard to their interaction with predators and the status of other prey species." The ERP working group is tasked with developing ERPs that are menhaden-specific that can account for the abundance of menhaden and their species role as a forage fish (Amendment 3 to the FMP, Anstead et al., 2021). Ospreys are non-finfish predators and can serve the ERP role which can allow management to practice informed decisions to develop harvest targets, assess menhaden's role as prey for upper trophic levels, and advance an ecosystem approach to fisheries management (EAFM) which considers multiple components of the ecosystem than just the target species (Patrick and Link, 2015). The menhaden population within Mobjack Bay is not currently adequate to sustain the osprey breeding population and we recommend that industrial purse seine fishing occur outside Chesapeake Bay.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

The animal study was reviewed and approved by Institutional Animal Care and Use Committee (IACUC-2021-05-03-14981-bjpaxt).

Author contributions

MA and BW designed and conducted the research. MA and BW performed the experiment, statistical analysis, and wrote the paper. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1172787/full#supplementary-material

References

Ahrenholz, D. W. (1991). Population biology and life history of the north. *Mar. Fisheries Rev.* 53, 3.

Annis, E., Friedland, K., and Uphoff, J. (2009). Ecosystem-based fisheries management for Chesapeake bay: menhaden background and issue briefs. *Maryland Sea Grant* UMSGTS-2009-08, M/2–M/9.

Anstead, K. A., Drew, K., Chagaris, D., Schueller, A. M., McNamee, J. E., Buchheister, A., et al. (2021). The path to an ecosystem approach for forage fish management: a case study of Atlantic menhaden. *Front. Mar. Sci.* 8, 491. doi: 10.3389/fmars.2021.607657

Ashmole, P. (1971). "Sea Bird ecology and the marine environment," in *Avian biology*, vol. 1 . Eds. D. S. Farner and J. R. King (New York: Academic Press).

Atlantic States Marine Fisheries Commission [ASMFC] (2017). *Atlantic Menhaden stock assessment update* (Arlington, VA: ASMFC). Available at: http://www.asmfc.org/files/commissionerManual/ISFMP/MenhadenAssessmentOverview_Aug2017.pdf.

Atlantic States Marine Fisheries Commission [ASMFC] (2004). "Atlantic menhaden stock assessment report for peer review," in *Atlantic states marine fisheries commission, stock assessment report no. 04-01 (Supplement)* (Arlington, VA: Atlantic States Marine Fisheries Commission), 145.

Bierregaard, R. O., Poole, A. F., and Washburn, B. E. (2014). Ospreys (Pandion haliaetus) in the 21st century: populations, migration, management, and research priorities. *J. Raptor Res.* 48 (4), 301–308.

Bowman, R., Powell, G. V. N., Hovis, J. A., Kline, N. C., and Wimers, T. (1989). Variations in reproductive success between subpopulations of the osprey (Pandion haliaetus) in south Florida. *Bull. Mar. Sci.* 44 (1), 245–250.

Brooks, M. E., Kristensen, K., Van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., et al. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *R J.* 9 (2), 378–400. doi: 10.32614/RJ-2017-066

Buchheister, A., Miller, T. J., and Houde, E. D. (2017). Evaluating ecosystem-based reference points for atlantic menhaden. *Mar. Coast. Fisheries* 9 (1), 457–478.

Butler, C. M., Rudershausen, P. J., and Buckel, J. A. (2010). Feeding ecology of Atlantic bluefin tuna (Thunnus thynnus) in north Carolina: diet, daily ration, and consumption of Atlantic menhaden (Brevoortia tyrannus). *Fishery Bull.* 108 (1), 56–59.

Byrd, M. A. (1987). "Osprey population studies," in *Virginia Nongame and endangered wildlife investigations* (Richmond, Virginia: Virginia Commission of Game and Inland Fisheries).

Byrd, M. A. (1988). "Osprey population studies," in *Virginia Nongame and endangered wildlife investigations* (Richmond, Virginia: Virginia Commission of Game and Inland Fisheries).

Byrd, M. A. (1990). "Osprey population studies," in *Virginia Nongame and endangered wildlife investigations* (Richmond, Virginia: Virginia Commission of Game and Inland Fisheries).

Cairns, D. K. (1988). Seabirds as indicators of marine food supplies. *Biol. Conserv.* 5, 261–271. doi: 10.1080/01965581.1987.10749517

S. Cramp and K. E. L. Simmons (Eds.) (1979). *The birds of the western palearctic* Vol. 11 (Oxford: Oxford University Press).

Cury, P., Shannon, L. J., Roux, J. P., Daskalov, G. M., Jarre, A., Moloney, C. L., et al. (2005). Trophodynamic indicators for an ecosystem approach to fisheries. *ICES J. Mar. Sci.* 62, 430–442. doi: 10.1016/j.icesjms.2004.12.006

Diamond, A. W., and Devlin, C. M. (2003). Seabirds as indicators of changes in marine ecosystems: ecological monitoring on machias seal island. *Environ. Monit. Assess.* 8, 153–175. doi: 10.1023/A:1025560805788

Drew, K., Cieri, M., Schueller, A. M., Buchheister, A., Chagaris, D., Nesslage, G., et al. (2021). Balancing model complexity, data requirements, and management objectives in developing ecological reference points for Atlantic menhaden. *Front. Mar. Sci.* 53. doi: 10.3389/fmars.2021.608059

Dryfoos, R. L., Cheek, R. P., and Kroger, R. L. (1973). Preliminary analysis of Atlantic menhaden, brevoortia tyrannus, migrations, population structure, survival and exploitation rates, and availability as indicated from tag returns. *Fish. Bull.* 71, 719–734.

Edwards, T. C. (1988). Temporal variation in prey preference patterns of adult ospreys. *Auk* 105, 244–251. doi: 10.2307/4087485

Einoder, L. D. (2009). A review of the use of seabirds as indicators in fisheries and ecosystem management. *Fisheries Res.* 95, 6–13. doi: 10.1016/j.fishres.2008.09.024

Eriksson, M. O. G. (1986). Fish delivery, production of young, and nest density of osprey (Pandion haliaetus) in southwest Sweden. *Can. J. Zoology* 64, 1961–1965. doi: 10.1139/z86-295

FAO (2020). "The state of world fisheries and aquaculture 2020," in *Brief. sustainability in action*(Rome: THE STATE OF THE WORLD series of the Food and Agriculture Organization of the United Nations). doi: 10.4060/ca9231en

Ferrer, M., Morandini, V., Baguena, G., and Newton, I. (2018). Reintroducing endangered raptors: a case study of supplementary feeding and removal of nestlings from wild populations. *J. Appl. Ecol.* 55, 1360–1367. doi: 10.1111/1365-2664.13014

Forbes, L. S. (1991). Hunger and food allocation among nestlings of facultatively siblicidal ospreys. *Behav. Ecol. Sociobiology* 29 (3), 189–195. doi: 10.1007/BF00166400

Furness, R. W. (1982). Competition between fisheries and seabird communities. *Adv. Mar. Biol.* 20, 225–309. doi: 10.1016/S0065-2881(08)60141-8

Furness, R. W., and Ainley, D. G. (1984). *Threat to seabird populations presented by commercial fisheries* (Cambridge, UK: ICBP).

Gannon, D. P., and Waples, D. M. (2004). Diets of coastal bottlenose dolphins from the US mid Atlantic coast differ by habitat. *Mar. Mammal Sci.* 20 (3), 527–545. doi: 10.1111/j.1748-7692.2004.tb01177.x

Glass, K. A. (2008). "Broad spatial trends in osprey provisioning, reproductive success, and population growth within lower Chesapeake bay," in *Dissertations, theses, and masters projects* (Virginia, USA: William & Mary. Paper), 1539626869. doi: 10.21220/s2-1n55-ph30

Glass, K. A., and Watts, B. D. (2009). Osprey diet composition and quality in high and low salinity areas of lower Chesapeake bay. *J. Raptor Res.* 43, 27–36. doi: 10.3356/JRR-08-22.1

Greene, E. P., Greene, A. E., and Freedman, B. (1983). *Foraging behavior and prey selection by ospreys in coastal habitats in Nova Scotia, Canada in biology and management of bald eagles and ospreys*. Ed. D. M. Bird (Ste. Anne de Bellevue, Quebec: Harpell Press), Pp. 257–267.

Grove, R. A., Henny, C. J., and Kaiser, J. L. (2009). Osprey: worldwide sentinel species for assessing and monitoring environmental contamination in rivers, lakes, reservoirs, and estuaries. *J. Toxicol. Environ. Health Part B* 12, 1,15–1,44. doi: 10.1080/10937400802545078

Hagan, J. M. (1986). Temporal patterns in pre-fledging survival and brood reduction in an osprey colony. *Condor* 88, 200–205. doi: 10.2307/1368916

Hartig, F. (2021). "DHARMa: residual diagnostics for hierarchical (Multi-level / mixed) regression models," in *R package version 0.4.4.* Available at: https://CRAN.Rproject.org/package=DHARMa.

Henny, C. J. (1983). "Distribution and abundance of nesting ospreys in the united states," in *Biology and management of bald eagles and ospreys* (Quebec, Canada: Harpell Press).

Henny, C. J., Grove, R. A., and Kaiser, J. L. (2008). Osprey distribution, reproductive success and contaminant burdens (OC pesticides, PCBs, PCDDs, PCDFs and mercury) along lower Columbia river 1997/1998 vs 2004. *Arch. Environ. Contam. Toxicol.* 54, 525–534. doi: 10.1007/s00244-007-9041-1

Henny, C. J., and Ogden, J. C. (1970). Estimated status of osprey populations in the united states. *J. Wildlife Manage.* 1, 214–217. doi: 10.2307/3799513

Henny, C. J., Smith, M. M., and Stotts, V. D. (1974). The 1973 distribution and abundance of breeding ospreys in the Chesapeake bay. *Chesapeake Sci.* 15 (3), 125-133. doi: 10.2307/1351027

Henny, C. J., and Wight, H. M. (1969). An endangered osprey population: estimates of mortality and production. *Auk* 86 (2), p.188–p.198. doi: 10.2307/4083495

Jamieson, I. G., Seymour, N. R., Bancroft, R. P., and Sullivan, R. (1983). Sibling aggression in nestling ospreys in Nova Scotia. *Can. J. Zoology* 61, 466–469. doi: 10.1139/z83-063

Johnson, B. L., Kaiser, J. L., Henny, C. J., and Grove, R. A. (2008). Prey of nesting ospreys on the Willamette and Columbia rivers, Oregon and Washington. *Northwest Sci.* 82 (3), 229–236. doi: 10.3955/0029-344X-82.3.229

June, F. C., and Nicholson, W. R. (1964). Age and size composition of the menhaden catch along the Atlantic coast of the united states 1958: with a brief review of the commercial fishery. *Special Scientific Report-Fisheries* 446, 1-26.

Kabuta, S. H., and Laane, R. W. P. M. (2003). Ecological performance indicators in the north Sea: development and application. *Ocean Coast. Manage.* 46, 277–297. doi: 10.1016/S0964-5691(03)00009-7

Kennedy, R. S. (1971). *Population dynamics of ospreys in tidewater, Virginia 1970 1971. M.A* (Williamsburg, VA: College of William and Mary), pp.83.

Kinkead, T. P. (1985). Age structure and dispersal of Chesapeake bay ospreys. *Dissertations, Theses, and Masters Projects* (William & Mary: Virginia, USA). Paper 1539625299. doi: :10.21220/s2-byss-qr76

Liljestrand, E. M., Wilberg, M. J., and Schueller, A. M. (2019). Estimation of movement and mortality of Atlantic menhaden during 1966–1969 using a Bayesian multi-state mark recovery model. *Fisheries Res.* 210, 204–213. doi: 10.1016/j.fishres.2018.10.015

Lind, G. S. (1976). *Production, nest site selection, and food habits of ospreys on deschutes national forest, oregon. M.S* (Corvallis, OR, USA: Oregon State University).

Link, J. (2010). *Ecosystem-based fisheries management: confronting tradeoffs* (Cambridge, UK: Cambridge University Press).

McLean, P. K. (1986). *The feeding ecology of the Chesapeake bay ospreys and the growth and behavior of their young* (Williamsburg, VA USA: The College of William and Mary).

McLean, P. K., and Byrd, M. A. (1991). Feeding ecology of Chesapeake bay ospreys and growth and behavior of their young. *Wilson Bull.* 103, 105–111.

McLeod, K. L., and Leslie, H. M. (2009). "Why ecosystem-based management" in *Ecosystem-based management for the oceans.* (Washington DC, USA: Island Press), pp. 3–12.

Monaghan, P., Walton, P., Wanless, S., Uttley, J. D., and Bljrns., M. D. (1994). Effects of prey abundance on the foraging behaviour, diving efficiency and time allocation of breeding guillemots uria aalge. *Ibis* 136 (2), 214–222.

Montevecchi, W. A. (1993). "Birds as indicators of change in marine prey stocks," in *Birds as monitors of environmental change.* Eds. R. W. Furness and J. J. D. Greenwood (London: Chapman and Hall), 217–265.

Nicholson, W. R. (1978). Movements and population structure of Atlantic menhaden indicated by tag returns. *Estuaries* 1 (3), 141–150. doi: 10.2307/1351455

NMFS (National Marine Fisheries Service) (2016). "Ecosystem-based fisheries management policy of the national marine fisheries service national oceanic and atmospheric administration," in *NMFS policy directive 01-120* (USA). Available at: www.nmfs.noaa.gov/op/pds/index.html.

Ogden, J. C., Baldwin, J. D., Bass, O. L., Browder, J. A., Cook, M. I., Frederick, P. C., et al. (2014). Waterbirds as indicators of ecosystem health in the coastal marine habitats of southern Florida: 1. selection and justification for a suite of indicator species. *Ecol. Indic.* 44, 148–163. doi: 10.1016/j.ecolind.2014.03.007

Patrick, W. S., and Link, J. S. (2015). Myths that continue to impede progress in ecosystem based fisheries management. *Fisheries* 40 (4), 155–160. doi: 10.1080/03632415.2015.1024308

Pauly, D., Alder, J., Booth, S., Cheung, W. W. L., Christensen, V., Close, C., et al. (2008). Fisheries in large marine ecosystems: descriptions and diagnoses. the UNEP large marine ecosystem report: a perspective on changing conditions in LMEs of the world's regional seas. *UNEP Regional Seas Rep. Stud.* 182), 23–40.

Pauly, D., and Zeller, D. (2016). Comments on FAOs state of world fisheries and aquacultur (SOFIA 2016) marine policy. *Marine Policy* 77, 2017, 176–181. doi: 10.1016/j.marpol.2017.01.006

Piatt, J. F., Harding, A. M., Shultz, M., Speckman, S. G., Van Pelt, T. I., Drew, G. S., et al. (2007). Seabirds as indicators of marine food supplies: cairns revisited. *Mar. Ecol. Prog. Ser.* 352, 221–234. doi: 10.3354/meps07078

Pikitch, E. K., Santora, C., Babcock, E. A., Bakun, A., Bonfil, R., Conover, D. O., et al. (2004). Ecosystem based fishery management. *Science* 305 (5682), 346–347. doi: 10.1126/science.1098222

Poole, A. F. (1982). Brood reduction in temperate and sub-tropical ospreys. *Oecologia* 53 (1), 111–119. doi: 10.1007/BF00377144

Poole, A. F. (1984). *Reproductive limitations in coastal ospreys: an ecological and evolutionary perspective* (Boston, MA: Unpubl. Ph.D. diss. Boston University).

Poole, A. F. (1989). *Ospreys: a natural and unnatural history (Vol. 246)* (Cambridge, UK: Cambridge University Press).

Poole, A. F. (2019). *Ospreys: the revival of a global raptor* (Baltimore, Maryland, USA: JHU Press).

Poole, A. F., Bierregaard, R. O., and Martell, M. S. (2002). *Osprey. birds of north America, no 683, ser.* Eds. A. F. Poole and F. Gill (Philadelphia, PA: Birds of North America, Inc).

Prevost, Y. A. (1983). "Osprey distribution and subspecies taxonomy," in *Biology and management of bald eagles and ospreys.* Ed. D. M. Bird (Montreal: Raptor Research Foundation), 157–174.

Pulliam, H. R. (1988). Sources, sinks, and population regulation. *Am. Nat.* 132 (5), 652–661. doi: 10.1086/284880

R Core Team (2020). *R: a language and environment for statistical computing* (Vienna, Austria: R Foundation for Statistical Computing). Available at: https://www.R-project.org/.

Reese, J. G. (1977). Reproductive success of ospreys in central Chesapeake bay. *Auk* 94 (2), 202–221. doi: 10.1093/auk/94.2.202

Richner, H. (1992). The effect of extra food on fitness in breeding carrion crows. *Ecology* 73, 330–335. doi: 10.2307/1938744

Scott, B. E., Sharples, J., Wanless, S., Ross, O. N., Frederiksen, M., and Daunt, F. (2006). "The use of biologically meaningful oceanographic indicies to separate the effects of climate and fisheries on seabird breeding success," in *Top predators in marine ecosystems.* Eds. I. L. Boyd, S. Wanless and C. J. Camphuysen (Cambridge: Cambridge University Press), 45–62.

Simons, L. S., and Martin, T. E. (1990). Food limitation of avian reproduction an experiment with the cactus wren. *Ecology* 71, 869–876. doi: 10.2307/1937358

Smith, C. R., Glover, A. G., Treude, T., Higgs, N. D., and Amon, D. J. (2015). Whale-fall ecosystems: recent insights into ecology, paleoecology, and evolution. *Annu. Rev. Mar. Sci.* 7, 571–596. doi: 10.1146/annurev-marine-010213-135144

Southeast Data Assessment and Review [SEDAR] (2020). *SEDAR 69 - Atlantic menhaden benchmark stock assessment report* (North Charleston SC: SEDAR).

Spitzer, P. R. (1980). *Dynamics of a discrete coastal breeding population of ospreys (Pandion haliaetus) in the northeastern united states during a period of decline and recovery 1969-1978* (New York: Cornell Univ.).

Spitzer, P. R., and Poole, A. F. (1980). Coastal ospreys between new York city and Boston: a decade of reproductive recovery 1969-1979. *Am. Birds.* 34, 233–242.

Steenhof, K., and Newton, I. (2007). *Assessing raptor nest success and productivity, in raptor research and management techniques.* Eds. D. M. Bird and K. L. Bildstein (Canada: Hancock House, Surrey, BC), 193–220.

Steidl, R. J., Griffin, C. R., and Niles, L. J. (1991). Contaminant levels of osprey eggs and prey reflect regional differences in reproductive success. *J. Wildlife Manage.* 601–608.

Stinson, C. H. (1976). *The evolutionary and ecological significance of the clutch size of the osprey* (Virginia: College of William and Mary. Williamsburg).

Truitt, R. V. (1969). The ospreys of great neck. *Atlantic Nat.* 24, 195–200.

Venables, W. N., and Ripley, B. D. (2002). "Random and mixed effects," in *Modern applied statistics with s* (New York, NY: Springer), 271–300.

Via, J. W. (1975). *Eggshell thinning and pesticide residues in ospreys from the lower Chesapeake bay* (Virginia: College of William and Mary. Williamsburg).

Watts, B. D., Byrd, M. A., and Watts, M. U. (2004). Status and distribution of breeding ospreys in breeding ospreys in Chesapeake bay: 1995-1996. *J. Raptor Res.* 38, 47–54.

Watts, B. D., and Paxton, B. J. (2007). Ospreys of the Chesapeake Bay: population recovery ecological requirements, and current threats. *Waterbirds*, 39–49. doi: 10.1675/1524-4695(2007)030[0039:OOTCBP]2.0.CO;2

Wiehn, J., and Korpimaki, E. (1997). Food limitation on brood size: experimental evidence in the Eurasian kestrel. *Ecology* 78, 2043–2050. doi: 10.1890/0012-9658(1997)078[2043:FLOBSE]2.0.CO;2

Wiemeyer, S. N. (1971). Reproductive success of potomac river ospreys–1970. *Chesapeake Sci.* 12 (4), 278–280. doi: 10.2307/1350918

Wiemeyer, S. N., Spitzer, P. R., Krantz, W. C., Lamont, T. G., and Cromartie, E. (1975). Effects of environmental pollutants on Connecticut and Maryland ospreys. *J. Wildlife Manage.* 1, 124–139. doi: 10.2307/3800475

Wiens, J. A., and Innis, G. S. (1974). Estimation of energy flow in bird communities: a population bioenergetics model. *Ecology* 55, 730–746. doi: 10.2307/1934410

Winberg, G. G. (1960). Rate of metabolism and food requirements of fishes. Fisheries research board of Canada translation series 194 ed.

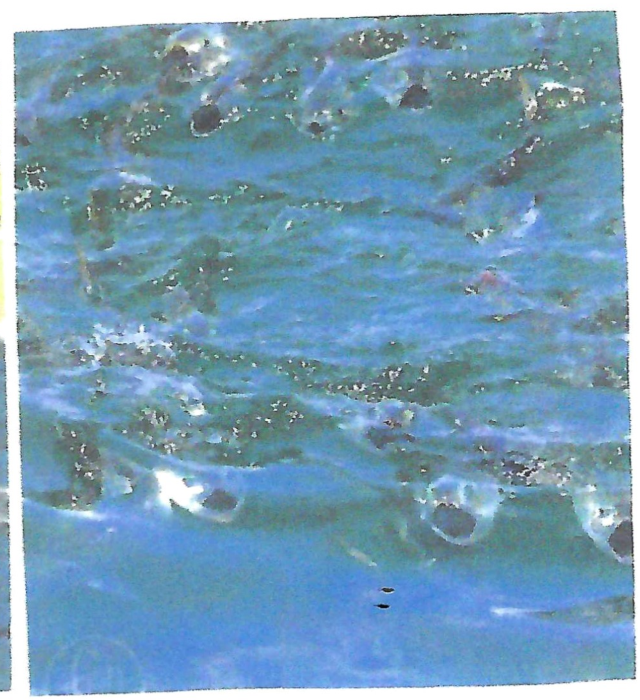
FWD: Menhaden
From: George Scocca george@nyangler.com
To: Tom foragematters@aol.com
Date: Mon, March 8, 2021 7:15am

Hello Tom:

I am the person that spearheaded the bill that has kept reduction fishing out of NY waters. The changes here have been unbelievable. I can talk about it all day. My single greatest accomplishment in 35 years of fisheries management.

The availability of bunker throughout our season has seen an increase in both charter and party boats carrying anglers to get in on our great striped bass fishery. Bass stick with their food source and this has kept a healthy population of stripers in our waters. It's sparked a number of for hire boats to carry more anglers than ever before.

It has also had a profound effect on our bird population. We now have about 12 dozen nest pair eagles on long island and the osprey population is thriving. All due to the amount of forage for them to eat.

And lets not forget the importance of their filtering our waters.

Thank you.

George R. Scocca
nyangler.com

Check out my Linkedin profile

Atlantic Menhaden age estimations from the reduction fishery 2019-2021
NOTE that age estimates are expressed in number of fish aged
Data are from NMFS Beaufort Laboratory, Ray Mroch 1/20/2023

Area	Age	Individuals 2019	2020*	2021*	Percentage 2019	2020	2021
	0	0	0	0	0.0%	0.0%	0.0%
	1	280	0	7	45.1%	0.0%	9.2%
	2	275	0	65	44.3%	0.0%	85.5%
Mid-Atlantic Region	3+	66	0	4	10.6%	0.0%	5.3%
	0	4	0	0	0.3%	0.0%	0.0%
	1	1099	87	430	73.5%	20.4%	66.7%
	2	321	338	209	21.5%	79.3%	32.4%
Chespeake Bay	3+	71	1	6	4.7%	0.2%	0.9%
	0	0	0	0	0.0%	0.0%	0.0%
	1	46	0	0	47.9%	0.0%	0.0%
	2	36	0	0	37.5%	0.0%	0.0%
Fall Fishery	3+	14	0	0	14.6%	0.0%	0.0%

* Samples from 2020 and 2021 were limited due to the stay-at-home orders resulting from the COVID-19 pandemic