Staff Summary for December 11-12, 2024

2. General Public Comment for Items Not on the Agenda

Today's Item **Information ☒** **Action ☐**

Receive public comment regarding topics within the Commission's authority that are not included on the agenda.

Summary of Previous/Future Actions

- **Today receive verbal requests and comments** **December 11-12, 2024**
- Consider granting, denying, or referring February 12-13, 2025

Background

This item is to provide the public an opportunity to address the Commission on topics not on the agenda. Staff may include written materials and comments received prior to the meeting as exhibits in the meeting binder (if received by the written comment deadline), or as supplemental comments at the meeting (if received by the supplemental comment deadline).

General public comments are categorized into two types: (1) requests for non-regulatory action and (2) informational-only comments. Under the Bagley-Keene Open Meeting Act, the Commission cannot discuss or take action on any matter not included on the agenda, other than to schedule issues raised by the public for consideration at future meetings. Thus, non-regulatory requests generally follow a two-meeting cycle (receipt and direction); the Commission will determine the outcome of non-regulatory requests received at today's meeting at the next regularly scheduled Commission meeting, following staff evaluation (currently February 12-13, 2025)

Significant Public Comments

Informational comments are provided as exhibits 1 through 8.

Recommendation

Commission staff: Consider whether to add any future agenda items to address issues that are raised during public comment.

Exhibits

1. Email from Jess Harris, shares commentary provided to State Water Resources Control Board regarding minimum flow recommendations on the Scott and Shasta Rivers, received October 24, 2024
2. A compilation of emails from Tom Hafer, President, Morro Bay Commercial Fisherman's Organization, each transmitting articles or surveys related to the impacts of offshore wind energy farms, received between October 25 and November 29, 2024
3. Letter from Karla A. Nemeth, Director, California Department of Water Resources, clarifies the State Water Project's take of white sturgeon in the Sacramento-San Joaquin Delta, received October 31, 2024

4. Email from Phoebe Lenhart, transmitting a copy of her letter to the California Wildlife Conservation Board requesting to add protection of Aleutian geese to the restoration goals of the proposed Lake Earl Wildlife Area, Del Norte County expansion project, received November 7, 2024
5. Email from John Lusk, notes that recent heavy rains have caused western Joshua trees to uproot and fall over, stating that it is unfair to require permits for handling downed trees, received November 27, 2024
6. Email from Donna Kalez, Chief Operating Officer of Dana Wharf Sportfishing & Whale Watching, expresses gratitude for Department Marine Region support of Fish for Life, a non-profit dedicated to expanding opportunities to special needs children, received November 29, 2024
7. Four postcards from members of the public asking to keep “ghost nets” (typically set gill nets) out of the ocean, received December 2, 2024
8. Email from Richard James, calls attention to plastic pollution in the ocean and efforts made to reduce plastic pollution within the shellfish industry, received December 2, 2024

Motion (N/A)

Outlook

Scott-Shasta Emergency Regulation/Alternatives Comments

From Jess Harris <[redacted]>

Date Thu 10/24/2024 06:36 AM

To WB-DWR-ScottShastaDrought <DWR-ScottShastaDrought@Waterboards.ca.gov>

Cc Andersen, Tony@CNRA <Tony.Andersen@resources.ca.gov>; brad.jones@epochtimesca.com <brad.jones@epochtimesca.com>; commentletters <commentletters@waterboards.ca.gov>; Wildlife DIRECTOR <DIRECTOR@wildlife.ca.gov>; erinmarie.ryan@mail.house.gov <erinmarie.ryan@mail.house.gov>; Ekdahl, Erik@Waterboards <Erik.Ekdahl@waterboards.ca.gov>; FGC <FGC@fgc.ca.gov>; gene.souza@klamathid.org <gene.souza@klamathid.org>; Theodora Johnson <theo@scottvalleyagwa.org>; Scruggs, Janae [redacted]>; justin.ly@noaa.gov <justin.ly@noaa.gov>; Michael Kobseff <mkobseff@co.siskiyou.ca.us>; martha_williams@fws.gov <martha_williams@fws.gov>; mpappas@svrcd.org <mpappas@svrcd.org>; NorthCoast <NorthCoast@Waterboards.ca.gov>; WB-EXEC-OPA <OPA@waterboards.ca.gov>; Publisher SNN <publisher@siskiyou.news>; rhaupt@co.siskiyou.ca.us <rhaupt@co.siskiyou.ca.us>; Rick Travis <rtravis@crpa.org>

Please see attached letter for comments.

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10/23/2024

California State Water Resources Control Board

Re: Scott-Shasta Emergency Regulation/Alternatives Comments

As we approach the end of 2024, your board is once again seeking to impose emergency regulations (E-regs) on the Scott and Shasta Rivers. The State Water Resources Control Board (SWRCB) has yet to provide factual, scientific data regarding minimum flow requirements for both watersheds. No comprehensive three- to five-year biological study, as mandated under the North American Model for Wildlife Conservation (the standard in the United States), has been conducted. The most recent study, conducted by McBain-Trush in 2013/2014, did not cover the entire Shasta River for minimum flow recommendations, focusing only on Reaches 1-3, which end at Parks Creek. Yet, the minimum flow recommendations are based on measurements taken at the Yreka gauge, much farther downstream. The SWRCB is requesting excessive minimum flow amounts. Both the Shasta and Scott River watersheds have adequate flows at 20 cubic feet per second (cfs), and a reasonable buffer of 5 cfs (totaling 25 cfs) should be considered more realistic.

Several important factors are being overlooked as the SWRCB continues to impose curtailments on ranchers and farmers. Upland management should be a top priority in both watersheds, as well as across the rest of the state. In particular, the Shasta River watershed is overgrown with Juniper trees, which consume a tremendous amount of water, affecting wetlands and stream flows. Additionally, there has been a lack of focus on recharge projects and efforts. During the fall and winter, excess flows in rivers and streams should be directed toward filling ponds, ditches, fields, and rejuvenating wetland habitats. The SWRCB cannot continue to harm Siskiyou County's farmers and ranchers without addressing these major underlying issues.

Emergency regulations are not necessary for Siskiyou County at this time. Governor Gavin Newsom's decision to continue the drought emergency declaration in Siskiyou County does not justify the SWRCB imposing harmful regulations on the citizens of the county. The SWRCB's actions give the impression of an out-of-touch, authoritarian, unelected agency that is overstepping its authority. A Kings County judge expressed a similar sentiment in recent litigation. The SWRCB should focus on serving the people of Siskiyou County and finding real solutions to water-related issues, rather than pandering to special interest groups that hold private, non-public meetings with staff. I urge you to decline reinstating the E-regs and allow local watermasters and groups to work toward a resolution.

Jess Harris

Siskiyou County Resident

[redacted]

Outlook

UK data reveals mass death of cetaceans in last 5 years

From mbcfo member <[redacted]>

Date Fri 10/25/2024 10:31 AM

To Debbie Arnold <debbie@debbieforslo.com>; Doug Boren <douglas.boren@boem.gov>; Andrea Chmelik <Andrea.Chmelik@asm.ca.gov>; Justin Cummings <Justin.Cummings@coastal.ca.gov>; Dobroski, Nicole@SLC <Nicole.Dobroski@slc.ca.gov>; FGC <FGC@fgc.ca.gov>; Flint, Scott@Energy <Scott.Flint@energy.ca.gov>; bgibson@co.slo.ca.us <bgibson@co.slo.ca.us>; Greg Haas <greg.haas@mail.house.gov>; Harland, Eli@Energy <Eli.Harland@energy.ca.gov>; Dr. Caryl Hart <Caryl.Hart@coastal.ca.gov>; Huckelbridge, Kate@Coastal <Kate.Huckelbridge@coastal.ca.gov>; Zara Landrum <zlandrum@morrobayca.gov>; Lucchesi, Jennifer@SLC <Jennifer.Lucchesi@slc.ca.gov>; Mattox, Jennifer@SLC <Jennifer.Mattox@slc.ca.gov>; Miller-Henson, Melissa [redacted]>; Michael Milstein <michael.milstein@noaa.gov>; Norway Embassy in Washington DC <emb.washington@mfa.no>; Payne, Elizabeth@Waterboards <Elizabeth.Payne@waterboards.ca.gov>; Reece, Elizabeth@Waterboards <Elizabeth.Reece@Waterboards.ca.gov>

Latest UK data reveals 5000 DEAD Whales, Dolphins and Porpoises in just 5 years
jasonendfield.medium.com

Tom Hafer, President
[redacted]

Outlook

Wind Farm Construction Can Harm Whales, Birds, Fisheries: New Federal Report

From mbcfo member <[redacted]>

Date Sun 10/27/2024 09:56 AM

To Debbie Arnold <debbie@debbieforslo.com>; Doug Boren <douglas.boren@boem.gov>; Andrea Chmelik <Andrea.Chmelik@asm.ca.gov>; Justin Cummings <Justin.Cummings@coastal.ca.gov>; Dobroski, Nicole@SLC <Nicole.Dobroski@slc.ca.gov>; FGC <FGC@fgc.ca.gov>; Flint, Scott@Energy <Scott.Flint@energy.ca.gov>; bgibson@co.slo.ca.us <bgibson@co.slo.ca.us>; Greg Haas <greg.haas@mail.house.gov>; Harland, Eli@Energy <Eli.Harland@energy.ca.gov>; Zara Landrum <zlandrum@morrobayca.gov>; Lucchesi, Jennifer@SLC <Jennifer.Lucchesi@slc.ca.gov>; Mattox, Jennifer@SLC <Jennifer.Mattox@slc.ca.gov>; Miller-Henson, Melissa[redacted]>; Michael Milstein <michael.milstein@noaa.gov>; Norway Embassy in Washington DC <emb.washington@mfa.no>; Payne, Elizabeth@Waterboards <Elizabeth.Payne@waterboards.ca.gov>; Reece, Elizabeth@Waterboards <Elizabeth.Reece@Waterboards.ca.gov>; John Romero <john.romero@boem.gov>; Suzy Watkins <suzyw@portsanluis.com>

Cc Paloma Aquirre <Paloma.Aguirre@coastal.ca.gov>; Dayna Bochco <Dayna.Bochco@coastal.ca.gov>; Raul Campillo <raul.campillo@coastal.ca.gov>; Justin Cummings <Justin.Cummings@coastal.ca.gov>; Linda Escalante <Linda.Escalante@coastal.ca.gov>; Meagan Harmon <Meagan.Harmon@coastal.ca.gov>; Dr. Caryl Hart <Caryl.Hart@coastal.ca.gov>; Huckelbridge, Kate@Coastal <Kate.Huckelbridge@coastal.ca.gov>; Susan Lowenberg <Susan.Lowenberg@coastal.ca.gov>; Ann Notthoff <Ann.Notthoff@coastal.ca.gov>; Katie Rice <Katie.Rice@coastal.ca.gov>; Charles Striplen <charles.striplen@coastal.ca.gov>; Effie Turnbull-Sanders <Effie.Turnbull-Sanders@coastal.ca.gov>; Roberto Uranga <Roberto.Uranga@coastal.ca.gov>; Mike Wilson <mike.wilson@coastal.ca.gov>

Tom Hafer, President

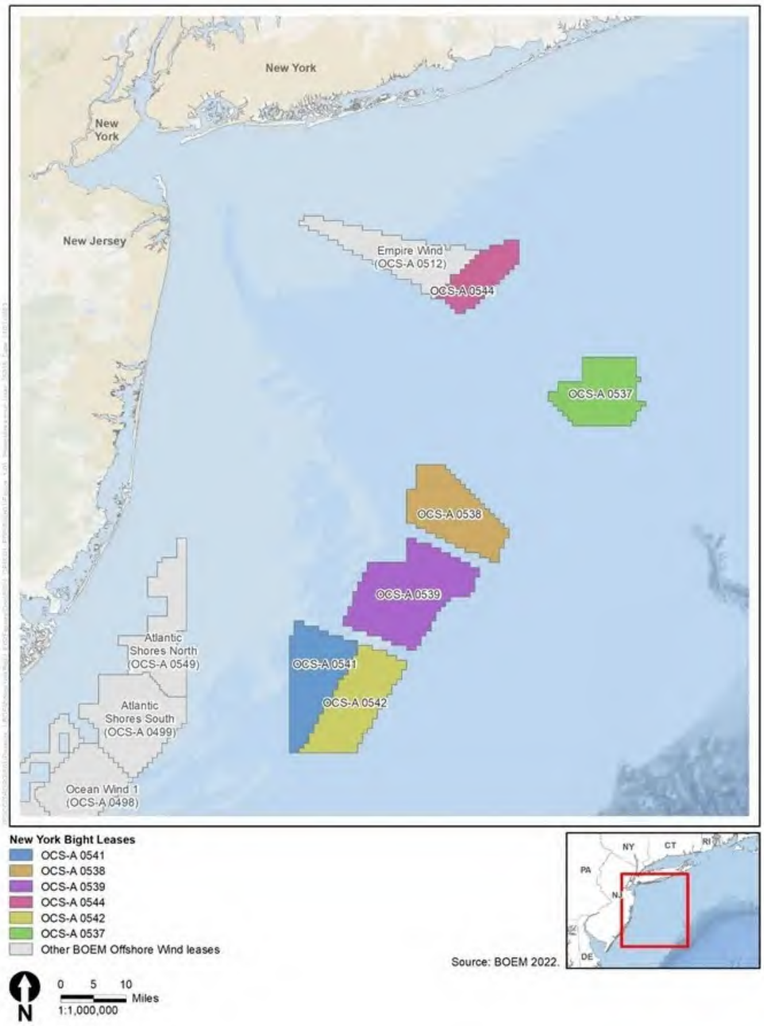
[redacted]

Wind Farm Construction Can Harm Whales, Birds, Fisheries: New Federal Report

A new federal report said whales, dolphins, birds and bats can all be injured by wind turbine construction, and offshore fishing harmed:

Updated Fri, Oct 25, 2024 at 5:59 pm ET

A humpback whale, which live off New Jersey and have experienced an increase in deaths since 2016, before wind turbine sonar surveys started. (Shutterstock)



These are the six existing wind farm sites that were already approved off the Jersey Shore and Long Island. (U.S. Bureau of Ocean Management)

JERSEY SHORE — The U.S. Bureau of Ocean Energy Management (BOEM) on Monday released a new report that said whales, dolphins, birds and more can indeed be harmed — and killed —by offshore wind farms.

BOEM also warned commercial fishing could be disrupted by wind farms.

The report is an environmental impact statement BOEM was required to conduct of these six existing wind farm sites that were previously approved off New Jersey/Long Island.

Wind turbine construction actually does increase the risk of injury to whales, particularly the underwater noise from pile-driving during construction, the federal report found. Turbine construction can permanently damage whales' hearing. Turbines can also lead to an "increased risk of individual injury and mortality due to vessel strikes" and entanglement in fishing gear.

Additionally, bats and birds could die by flying into moving wind turbines.

You can read the 620-page report here. Risks to marine life begin on page 609, under what BOEM calls "unavoidable adverse impacts."

It reads as follows:

"Even with AMMM (avoidance, minimization, mitigation and monitoring) measures, development would still result in unavoidable adverse impacts," the report reads. "Most potential unavoidable adverse impacts associated with the Proposed Action (building of wind turbines) would occur during the construction phase and would be temporary."

Bats: Displacement and avoidance behavior due to habitat loss/alteration, equipment noise and vessel traffic. Individual mortality due to collisions with operating WTGs (WTG stands for wind turbine generator)

Birds: Displacement and avoidance behavior due to habitat loss or alteration, equipment noise, and vessel traffic. Individual mortality due to collisions with operating WTGs (wind turbines)

Marine mammals: Increased risk of injury (TTS or PTS, scientific terms for temporary or permanent loss of hearing) to individuals due to underwater noise from pile-driving activities during construction. Disturbance (behavioral effects) and acoustic masking due to underwater noise from pile-driving, vessel traffic, aircraft, wind turbine operation, and dredging during construction and operations. Presence of (wind turbine) structures resulting in hydrodynamic effects that influence primary and secondary productivity and availability of prey and forage resources. Increased risk of individual injury and mortality due to vessel strikes. Increased risk of individual injury and mortality associated with fisheries gear.

Sea turtles: Increased risk for individual injury and mortality due to vessel strikes during construction and installation, O&M (operations and maintenance), and conceptual decommissioning. Increased risk of individual injury and mortality associated with fisheries gear. Disturbance, displacement and avoidance behavior due to habitat disturbance and underwater noise during construction.

On page 106, the report said:

"Moderate impacts are expected for non-NARW (North American Right Whale) marine mammals due to non-offshore wind-related fishing gear utilization, pile driving and UXO detonation noise (UXO detonations are underwater explosions of any type), and vessel strikes ... Major impacts on the North American Right Whale would be expected from vessel strikes and non-offshore wind-related fishing gear utilization; moderate due to presence of structures and noise from impact pile-driving and UXO detonation."

Commercial Fisheries and For-Hire Recreational Fishing: Disruption of access or temporary restriction in harvesting activities due to construction; disruption of harvesting activities during operations of offshore wind facilities; changes in vessel transit and fishing operation patterns; changes in risk of gear entanglement or availability of target species; Loss of employment or income due to disruption to commercial fishing, for-hire recreational fishing, or marine recreation businesses; Hindrances to subsistence fishing due to offshore construction and operation of the offshore wind facilities. (Pages 610-611)

A BOEM spokesman said the federal agency is required to list all the "potential unavoidable adverse impacts" associated with wind farms off New Jersey. He also said the risks can be mitigated through the measures they listed here.

"Populations are expected to recover completely when stressors are removed," BOEM wrote. BOEM also said if wind turbine construction is spaced out, and does not happen at all six sites at once, the sound damage from underwater pile driving will be reduced.

NJ DEP spokesman Larry Hajna said the DEP had not thoroughly reviewed the 620-page report "and therefore can't comment on it at this time."

But he did say:

"There is no documented scientific evidence linking offshore wind energy activities to whale deaths. The sounds produced during different offshore wind development phases are insufficient to cause mortality. Vessel collisions have the potential to injure or kill whales. However, offshore wind vessels comprise a very small portion of all vessels in the marine environment, and they operate in a more precautionary manner to avoid the types of collisions that occur with other industries."

BOEM agreed boat strikes are likely the reason why there has been an increase in humpback whale deaths since 2016. On page 238:

"A recent uptick in large whale strandings during late 2022 and early 2023 along the New Jersey and New York coastlines, primarily of humpback whales, is currently being evaluated by National Marine Fisheries Service. However, there is no causal connection between recent offshore wind development and large whale mortality, and such assumption is contrary to the scientific consensus. The overwhelming scientific consensus is that offshore wind activity is not a cause of these marine mammal mortalities. Instead, the scientific community has determined the Unusual Mortality Event for humpback whales is primarily caused by non-offshore-wind vessel strikes and fishing gear entanglements."

NJ Congressman Chris Smith, a Republican who is against the wind farms, said the federal government is "gaslighting" the public. He also pointed to a similar report BOEM released in May about Atlantic Shores wind farm, with the same adverse impact warnings (page 549).

“Those who are recklessly advancing offshore wind at all costs — including and especially officials at BOEM and NOAA and in Gov. Murphy’s administration — have been gaslighting the general public for years by disingenuously insisting that the rapid, unprecedented industrialization of our ocean will not have adverse impacts,” said Rep. Smith. “In fact, we know that these projects will cause significant harm in part from these federal agencies, which are required by law to list all the anticipated adverse impacts. Fortunately, local anglers and residents haven’t been fooled."

Smith said an independent audit, which he called for, is currently underway on the impact wind farms will have on whales, other marine life and commercial fishing.

Not a single wind turbine has been built yet off the Jersey Shore. However, starting in 2019, ocean floor surveying was done off Ocean, Atlantic and Cape May counties, to study the seabed for suitable turbine locations.

BOEM, the National Oceanic and Atmospheric Administration (NOAA) and the NJ DEP all maintain the seismic sound waves used in surveying do not harm whales. This week, NJDEP spokesman Hajna said their 2023 statement is still accurate: There is no evidence that sonar used in offshore wind surveys causes whale deaths.

So far, two major companies have pulled out of their plans to build wind farms off New Jersey, saying it is too expensive.

Last Halloween, Danish company Orsted made the surprise 3 a.m. announcement they were pulling out of their plans to build Ocean Wind 1 and 2 off Atlantic City. This was after the NJ Legislature gave them nearly $500 million in tax breaks to build the wind farms.

Then, in January, Equinor and British Petroleum (BP) announced they terminated their agreement with New York state to build Empire Wind 2, which would have been built on 80,000 acres of ocean about 19 miles out and stretched from Sandy Hook to Long Branch.

BP cited "inflation, interest rates and supply chain disruptions" as reasons for canceling the project. The company also said there are "changed economic circumstances on an industry-wide scale.

BOEM said their Oct. 21 report is the result of five public meetings it held in early 2024, and "eight regional environmental justice forums between 2022 and 2024 to receive input on the wind farms from local community members, government partners and ocean users."

"The BOEM announcement says it conferred with 'stakeholders,'" said Bob Stern of Save LBI, which is against the wind farms. "I don't know who those were, but we were not invited to the party."

His group is suing the federal government to stop any wind farm construction.

Outlook

Shocking Rise In Whale, Dolphin, & Porpoise Strandings As Wind Farms Proliferate Around British Coast

From mbcfo member <[redacted]>

Date Wed 10/30/2024 07:14 AM

To Debbie Arnold <debbie@debbieforslo.com>; Doug Boren <douglas.boren@boem.gov>; Andrea Chmelik <Andrea.Chmelik@asm.ca.gov>; Dobroski, Nicole@SLC <Nicole.Dobroski@slc.ca.gov>; FGC <FGC@fgc.ca.gov>; Flint, Scott@Energy <Scott.Flint@energy.ca.gov>; bgibson@co.slo.ca.us <bgibson@co.slo.ca.us>; Greg Haas <greg.haas@mail.house.gov>; Harland, Eli@Energy <Eli.Harland@energy.ca.gov>; Zara Landrum <zlandrum@morrobayca.gov>; Lucchesi, Jennifer@SLC <Jennifer.Lucchesi@slc.ca.gov>; Mattox, Jennifer@SLC <Jennifer.Mattox@slc.ca.gov>; Miller-Henson, Melissa[redacted]>; Michael Milstein <michael.milstein@noaa.gov>; Norway Embassy in Washington DC <emb.washington@mfa.no>; Payne, Elizabeth@Waterboards <Elizabeth.Payne@waterboards.ca.gov>; Reece, Elizabeth@Waterboards <Elizabeth.Reece@Waterboards.ca.gov>; John Romero <john.romero@boem.gov>; Suzy Watkins <suzyw@portsanluis.com>; Clint Weirick <clint.weirick@sen.ca.gov>

Tom Hafer, President

[redacted]

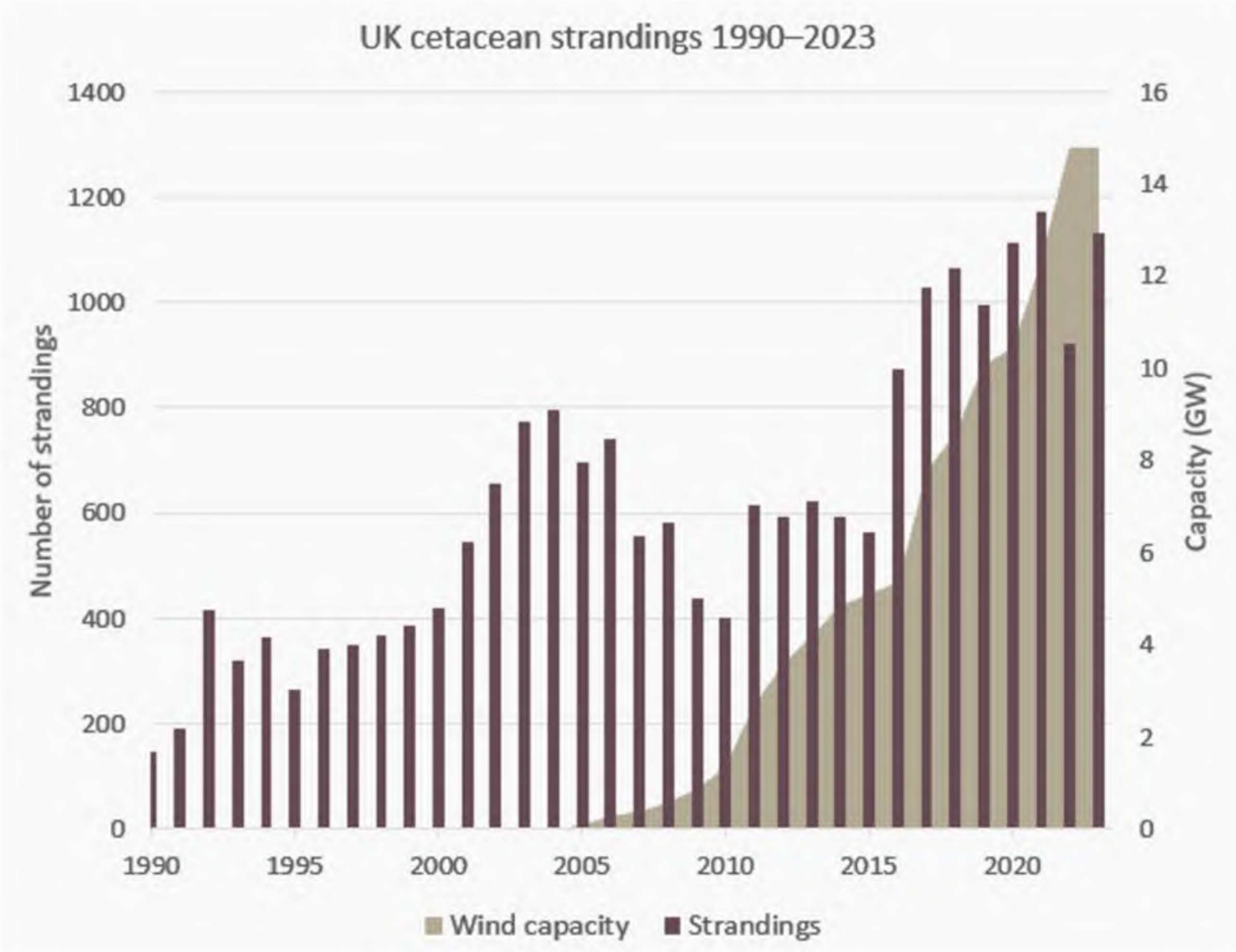
Shocking Rise In Whale, Dolphin, & Porpoise Strandings As Wind Farms Proliferate Around British Coast

Authored by Chris Morrison via DailySceptic.org,

Over the last decade as offshore wind farms proliferated around the U.K., **there has been a disturbing rise in coastline strandings of whales, dolphins and porpoises.** Since the turn of the century, strandings have more than doubled and are now running at over 1,000 animals a year. The slaughter has been largely ignored by the mainstream media that runs with the agreed narrative that offshore wind is environmentally friendly and is the key to achieving Net Zero by 2050.

In fact, **wind turbines, whether on or off the shore, are a clear danger to many endangered species** and concerns are mounting about their widespread and harmful effects on the natural world. Years ago, the great cause in environmentalism was to save the whales, but these concerns seem to have abated of late, while the slaughter of millions of onshore bats, along with the destruction of many types of large raptors, is simply ignored.

Andrew Montford of Net Zero Watch has updated his graph on the stranding of U.K. cetaceans and compared it to the rise of offshore wind capacity.



Both totals have soared in recent years. Is there a causal link? Perhaps not one that would inconvenience Net Zero fanatics, but Montford says the suggestion of a causal relationship "remains very strong".

The *Daily Sceptic* has reported in the past about the **mounting casualties of whales stranded off the north eastern coast of the United States in the wake of massive offshore windfarm construction.** There have been around 300 fatalities in the last five years, and many suggest the extensive sonar soundings, pile driving and heavy concentrated vessel traffic is causing havoc with aquatic feeding, breeding and migration up and down the coast.

The latest U.K. stranding figures have been reported to Ascobans, a UN environmental conservation body for cetaceans in the NE Atlantic. Commenting on the "shocking" figures, the environmental writer and campaigner Jason Endfield called them ***"a wake-up call to those planning to further industrialise our seas in the name of renewable energy, and especially offshore wind farms".*** In his view, it made no sense to increase ocean noise to levels that are "literally unbearable for marine mammals".

The great cover-up of this environmental disaster continues with massive industrial parks being erected around the coasts of many countries. In the U.K., the incoming Labour government is committed to a massive expansion with the Mad Miliband spraying around billions of pounds in additional subsidies to boost an industry that would not exist in a free market.

To the fore in blowing smoke over the issue is Greenpeace USA's senior oceans campaigner Arlo Hemphill who claims there is "no evidence whatsoever" connecting wind turbines to whale deaths. ***"It's just a cynical disinformation campaign,"*** says another Greenpeace spokesman. The mainstream media often goes along with this narrative as shown by recent tweets from *Agence France-Presse* reporter Manon Jacob. He dismissed the focus on wind farms as a red herring "when offshore wind remains thus far marginal in the U.S. and scientific evidence of large marine mammal deaths is lacking". This is the same Jacob who wrote a recent 'fact check' of the *Daily Sceptic* that was so bad and misleading it should feature in future journalism schools as an example of how not to criticise well-sourced material.

The investigative science journalist Jo Nova has a different take on the matter:

"Researchers have known since at least 2013 that pile drivers were permanently deafening porpoises, leaving them presumably to die miserable deaths wandering blindly through dark or murky seas. Where were all the professors of marine science, paid by the public to know these things, and where was the BBC?"

Spread the word, she continued.

Fifty years ago, environmentalists would have raised hell about a thousand dead whales and dolphins. Now they are part of the cover-up. "They don't want to draw attention to the blubber on the beach in case people start asking hard questions," she observed.

There are however some signs that the 'nothing to see here, guv' line is starting to crack. A recent essay in *Watts*

Up With That? suggested that an impact statement from the U.S. Bureau of Ocean Energy Management (BOEM) had finally acknowledged the harm caused by offshore wind farms. Examining leases off the New Jersey and New York coast covering over 488,000 acres, the BOEM hints that these developments are not entirely benign "despite being repeatedly framed as environmentally friendly solutions to the climate crisis". Marine mammals, sea turtles, birds and fish could suffer due to noise, habitat displacement and changes in migration patterns, it is said. Even bats, says *WUWT?*, which are not typically associated with offshore environments, could be affected.

The essay noted that this latest BOEM work may signal a more cautious approach, ***"perhaps influenced by increasing legal challenges, public backlash, and even emerging scientific research indicating that wind turbines are not as harmless as once believed".***

Outlook

Please add these Harvard Studies into your administrative records

From mbcfo member <[redacted]>

Date Thu 10/31/2024 12:49 PM

To Debbie Arnold <debbie@debbieforslo.com>; Doug Boren <douglas.boren@boem.gov>; Andrea Chmelik <Andrea.Chmelik@asm.ca.gov>; Dobroski, Nicole@SLC <Nicole.Dobroski@slc.ca.gov>; FGC <FGC@fgc.ca.gov>; Flint, Scott@Energy <Scott.Flint@energy.ca.gov>; bgibson@co.slo.ca.us <bgibson@co.slo.ca.us>; Greg Haas <greg.haas@mail.house.gov>; Harland, Eli@Energy <Eli.Harland@energy.ca.gov>; Zara Landrum <zlandrum@morrobayca.gov>; Lucchesi, Jennifer@SLC <Jennifer.Lucchesi@slc.ca.gov>; Mattox, Jennifer@SLC <Jennifer.Mattox@slc.ca.gov>; Miller-Henson, Melissa[redacted]>; Michael Milstein <michael.milstein@noaa.gov>; Norway Embassy in Washington DC <emb.washington@mfa.no>; Payne, Elizabeth@Waterboards <Elizabeth.Payne@waterboards.ca.gov>; Reece, Elizabeth@Waterboards <Elizabeth.Reece@Waterboards.ca.gov>; John Romero <john.romero@boem.gov>; Suzy Watkins <suzyw@portsanluis.com>; Clint Weirick <clint.weirick@sen.ca.gov>

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Tom Hafer, President

[redacted]

The Harvard Gazette

SCIENCE & TECH

The down side to wind power

Leah Burrows | SEAS Communications

October 4, 2018 ▪ 6 min read

Wind farms will cause more environmental impact than previously thought

When it comes to energy production, there's no such thing as a free lunch, unfortunately.

As the world begins its large-scale transition toward low-carbon energy sources, it is vital that the pros and cons of each type are well understood and the environmental impacts of renewable energy, small as they may be in comparison to coal and gas, are considered.

In two papers — published today in the journals **Environmental Research Letters** and **Joule** — Harvard University researchers find that the transition to wind or solar power in the U.S. would require five to 20 times more land than previously thought, and, if such large-scale wind farms were built, would warm average surface temperatures over the continental U.S. by 0.24 degrees Celsius.

“Wind beats coal by any environmental measure, but that doesn’t mean that its impacts are negligible,” said David Keith, the Gordon McKay Professor of Applied Physics at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) and senior author of the papers. “We must quickly transition away from fossil fuels to stop carbon emissions. In doing so, we must make choices between various low-carbon technologies, all of which have some social and environmental impacts.”

Keith is also professor of public policy at the Harvard Kennedy School.

One of the first steps to understanding the environmental impact of renewable technologies is to understand how much land would be required to meet future U.S. energy demands. Even starting with today’s energy demands, the land area and associated power densities required have long been debated by energy experts.

In previous research, Keith and co-authors modeled the generating capacity of large-scale wind farms and concluded that real-world wind power generation had been overestimated because they neglected to accurately account for the interactions between turbines and the atmosphere.

> “The direct climate impacts of wind power are instant, while the benefits

> **of reduced emissions accumulate slowly."**
>
> **— David Keith**

In 2013 research, Keith described how each wind turbine creates a "wind shadow" behind it where air has been slowed down by the turbine's blades. Today's commercial-scale wind farms carefully space turbines to reduce the impact of these wind shadows, but given the expectation that wind farms will continue to expand as demand for wind-derived electricity increases, interactions and associated climatic impacts cannot be avoided.

What was missing from this previous research, however, were observations to support the modeling. Then, a few months ago, the U.S. Geological Survey released the locations of 57,636 wind turbines around the U.S. Using this data set, in combination with several other U.S. government databases, Keith and postdoctoral fellow Lee Miller were able to quantify the power density of 411 wind farms and 1,150 solar photovoltaic plants operating in the U.S. during 2016.

"For wind, we found that the average power density — meaning the rate of energy generation divided by the encompassing area of the wind plant — was up to 100 times lower than estimates by some leading energy experts," said Miller, who is the first author of both papers. "Most of these estimates failed to consider the turbine-atmosphere interaction. For an isolated wind turbine, interactions are not important at all, but once the wind farms are more than five to 10 kilometers deep, these interactions have a major impact on the power density."

The observation-based wind power densities are also much lower than important estimates from the U.S. Department of Energy and the Intergovernmental Panel on Climate Change.

For solar energy, the average power density (measured in watts per meter squared) is 10 times higher than wind power, but also much lower than estimates by leading energy experts.

This research suggests that not only will wind farms require more land to hit the proposed renewable energy targets but also, at such a large scale, would become an active player in the climate system.

The next question, as explored in the journal Joule, was how such large-scale wind farms would impact the climate system.

> "If your perspective is the next 10 years, wind power actually has — in some respects — more climate impact than coal or gas. If your perspective is the next thousand years, then wind power has enormously less climatic impact than coal or gas."
>
> — David Keith

To estimate the impacts of wind power, Keith and Miller established a baseline for the 2012-2014 U.S. climate using a standard weather-forecasting model. Then, they covered one-third of the continental U.S. with enough wind turbines to meet present-day U.S. electricity demand. The researchers found this scenario would warm the surface temperature of the continental U.S. by 0.24 degrees Celsius, with the largest changes occurring at night when surface temperatures increased by up to 1.5 degrees. This warming is the result of wind turbines actively mixing the atmosphere near the ground and aloft while simultaneously extracting from the atmosphere's motion.

This research supports more than 10 other studies that observed warming near operational U.S. wind farms. Miller and Keith compared their simulations to satellite-based observational studies in North Texas and found roughly consistent temperature increases.

Miller and Keith are quick to point out the unlikeliness of the U.S. generating as much wind power as they simulate in their scenario, but localized warming occurs in even smaller projections. The follow-on question is then to understand when the growing benefits of reducing emissions are roughly equal to the near-instantaneous impacts of wind power.

The Harvard researchers found that the warming effect of wind turbines in the continental U.S. was actually larger than the effect of reduced emissions for the first century of its operation. This is because the warming effect is predominantly local to the wind farm, while greenhouse gas concentrations must be reduced globally before the benefits are realized.

Miller and Keith repeated the calculation for solar power and found that its climate impacts were about 10 times smaller than wind's.

“The direct climate impacts of wind power are instant, while the benefits of reduced emissions accumulate slowly,” said Keith. “If your perspective is the next 10 years, wind power actually has — in some respects — more climate impact than coal or gas. If your perspective is the next thousand years, then wind power has enormously less climatic impact than coal or gas.

“The work should not be seen as a fundamental critique of wind power,” he said. “Some of wind’s climate impacts will be beneficial — several global studies show that wind power cools polar regions. Rather, the work should be seen as a first step in getting more serious about assessing these impacts for all renewables. Our hope is that our study, combined with the recent direct observations, marks a turning point where wind power’s climatic impacts begin to receive serious consideration in strategic decisions about decarbonizing the energy system.”

This research was funded by the Fund for Innovative Climate and Energy Research.

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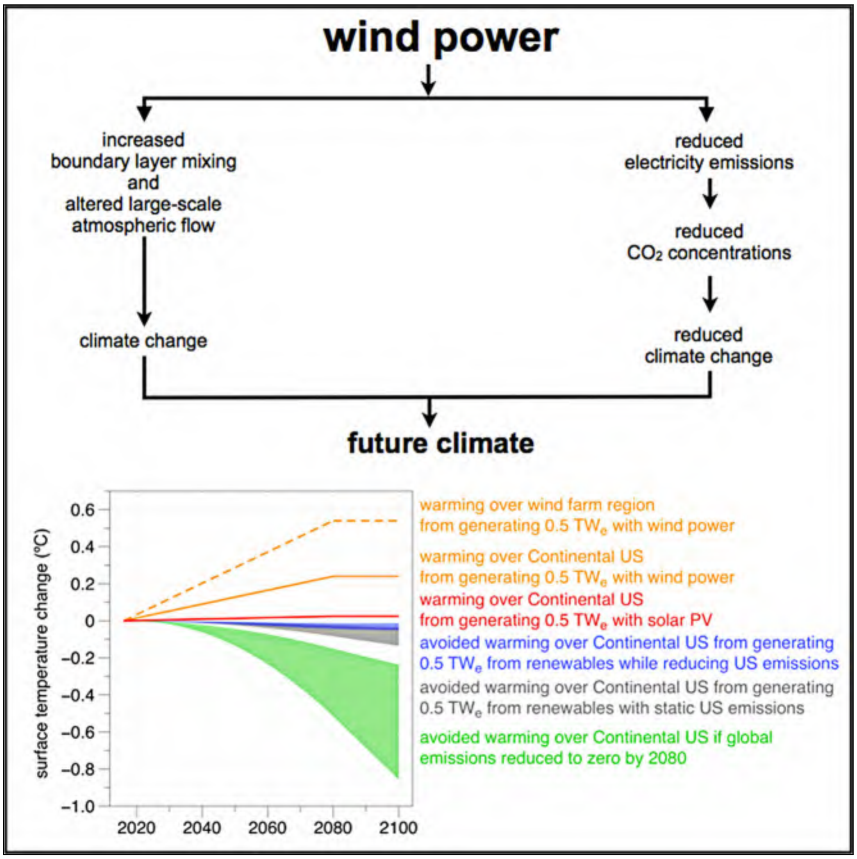
Climatic Impacts of Wind Power



Wind beats fossil, but wind power does cause non-negligible climatic impacts. This study advances work on wind power's climate impacts by: (1) providing a mechanistic explanation for wind turbines' climate impacts by comparing numerical simulations with observations, (2) filling a current gap between small- and very-large-scale wind power simulation studies, (3) making the first quantitative comparison between wind power's climatic impacts and benefits, and (4) using the same framework to make a quantitative comparison with solar power.

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HIGHLIGHTS

Wind power reduces emissions while causing climatic impacts such as warmer temperatures

Warming effect strongest at night when temperatures increase with height

Nighttime warming effect observed at 28 operational US wind farms

Wind's warming can exceed avoided warming from reduced emissions for a century

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Climatic Impacts of Wind Power

Lee M. Miller[1,3,*] and David W. Keith[1,2,*]

SUMMARY

We find that generating today's US electricity demand (0.5 TW_e) with wind power would warm Continental US surface temperatures by 0.24°C. Warming arises, in part, from turbines redistributing heat by mixing the boundary layer. Modeled diurnal and seasonal temperature differences are roughly consistent with recent observations of warming at wind farms, reflecting a coherent mechanistic understanding for how wind turbines alter climate. The warming effect is: small compared with projections of 21st century warming, approximately equivalent to the reduced warming achieved by decarbonizing global electricity generation, and large compared with the reduced warming achieved by decarbonizing US electricity with wind. For the same generation rate, the climatic impacts from solar photovoltaic systems are about ten times smaller than wind systems. Wind's overall environmental impacts are surely less than fossil energy. Yet, as the energy system is decarbonized, decisions between wind and solar should be informed by estimates of their climate impacts.

Context & Scale

Wind power can impact the climate by altering the atmospheric boundary layer, with at least 40 papers and 10 observational studies now linking wind power to climatic impacts. We make the first comparison between the climatic impacts of large-scale wind power and site-scale observations, finding agreement that warming from wind turbines is largest at night. Wind power's climatic impacts will continue to expand as more are installed.

Do these impacts matter? How do these impacts compare to the climate benefits of reducing emissions? We offer policy-relevant comparisons: wind's climatic impacts are about 10 times larger than solar photovoltaic systems per unit energy generated. We explore the temporal trade-off between wind's climatic impacts and the climate benefits it brings by reducing emissions as it displaces fossil fuels. Quantitative comparisons between low-carbon energy sources should inform energy choices in the transition to a carbon-free energy system.

INTRODUCTION

To extract energy, all renewables must alter natural energy fluxes, so climate impacts are unavoidable, but the magnitude and character of climate impact varies widely. Wind turbines generate electricity by extracting kinetic energy, which slows winds and modifies the exchange of heat, moisture, and momentum between the surface and the atmosphere. Observations show that wind turbines alter local climate,[1–10] and models show local- to global-scale climate changes from the large-scale extraction of wind power.[11–15] Previous studies have assessed climate impacts of hydropower,[16] biofuels,[17] and solar photovoltaic systems (PVs).[18] Rapid expansion of renewable energy generation is a cornerstone of efforts to limit climate change by decarbonizing the world's energy system. In addition to climate benefits, wind and solar power also reduce emissions of criteria pollutants (NO_x, SO_x, and $PM_{2.5}$) and toxic pollutants such as mercury that cause significant public health impacts.[19,20] The climate impacts of wind and solar are small compared with the impacts of the fossil fuels they displace, but they are not necessarily negligible. Improved understanding of the environmental trade-offs between renewables would inform choices between low-carbon energy sources. With growth of wind and solar PVs far outstripping other renewables,[21] we combine direct observations of onshore wind power's impacts with a continental-scale model, and compare it to prior estimates of PVs' impacts to assess the relative climate impacts of wind and solar energy per unit energy generation.

Climatic impacts due to wind power extraction were first studied using general circulation models (GCMs). These studies found statistically significant climatic impacts within the wind farm, as well as long-distance teleconnections, with impacts outside the wind farm sometimes as large in magnitude as impacts inside the wind farm.[11–13,22] Note that such impacts are unlike greenhouse gas (GHG)-driven warming, as in some cases wind power's climatic impacts might counteract such GHG warming—at least four studies have found that mid-latitude wind power extraction can cool the Arctic.[11,12,23,24] However, these studies often used idealized or unrealistic distributions of turbines installed at unrealistic scales. Model simulations of geometrically simple, isolated wind farms at smaller scales of 3,000–300,000 km^2 (10- to 1,000 times larger than today's wind farms) in windy locations found substantial reductions in wind speed and changes in atmospheric boundary layer (ABL) thickness, as well as differences in temperature,[11,13,14,24] precipitation,[14,25] and vertical atmospheric exchange.[15,26]

We want to assess wind power's climate impacts per unit of energy generation, yet wind's climatic impacts depend on local meteorology and on non-local climate teleconnections. These twin dependencies mean that wind power's impacts are strongly dependent on the amount and location of wind power extraction, frustrating the development of a simple impact metric.

As a step toward an improved policy-relevant understanding, we explore the climatic impacts of generating 0.46 TW_e of wind-derived electricity over the Continental US. This scale fills a gap between the smaller isolated wind farms and global-scale GCM. We model a uniform turbine density within the windiest one-third of the Continental US, and vary the density parametrically.

Our 0.46 TW_e *benchmark scenario* is ~18 times the 2016 US wind power generation rate.[21] We intend it as a plausible scale of wind power generation if wind power plays a major role in decarbonizing the energy system in the latter half of this century. For perspective, the benchmark's electricity generation rate is only 14% of current US primary energy consumption,[25] about the same as US electricity consumption,[27] and about 2.4 times larger than the projected 2050 US wind power generation rate of the *Central Study* in the Department of Energy's (DOE) recent *Wind Vision*.[28] Finally, it is less than one-sixth the technical wind power potential over about the same windy areas of the US as estimated by the DOE.[28,29]

Modeling Framework

We use the WRF v3.3.1 high-resolution regional model[30] with a domain that encompasses the Continental US, forced by boundary conditions from the North American Regional Reanalysis.[31] The *wind farm region* is more than 500 km from the model boundaries, and encompasses only 13% of the domain (shown in Figure 1A). The model configuration used dynamic soil moisture and 31 vertical levels with 3 levels intersecting the turbine's rotor and 8 levels representing the lowermost kilometer. The model is run for a full year after a 1-month spin-up using horizontal resolutions of 10 and 30 km. The wind turbine parametrization was originally released with WRF v3.3,[32] and represents wind turbines as both a momentum sink and turbulent kinetic energy (TKE) source. We updated the wind turbine parameterization to make use of the thrust, power, and TKE coefficients from a Vestas V112 3 MW. This treatment of wind power is very similar to previous modeling studies.[14,15,24]

The advantage of the regional model is that we can use a horizontal and vertical resolution substantially higher than previous global modeling studies,[11–13,22,23,26,33,34] allowing better representation of the interactions of the wind turbines with the ABL. The disadvantage of using prescribed boundary conditions is that our simulations will underestimate the global-scale climatic response to wind power extraction compared with a global model with equivalent resolution, which would allow the global atmosphere to react to the increased surface drag over the US and would reveal climate teleconnections.

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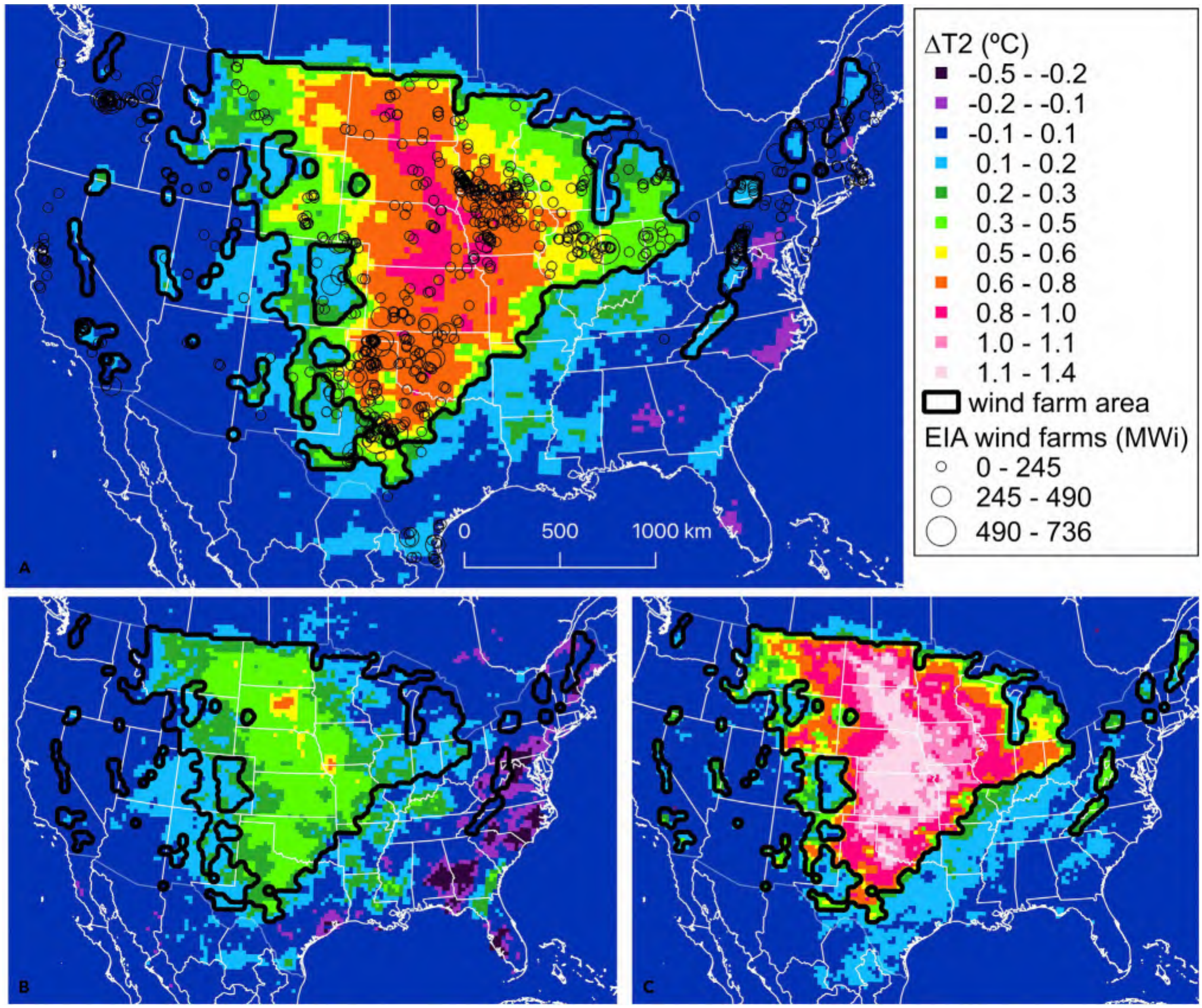

Figure 1. Temperature Response to Benchmark Wind Power Deployment (0.5 MW km^{-2})

(A–C) Maps are 3-year mean of perturbed minus 3-year mean of control for 2-m air temperatures, showing (A) entire period, (B) daytime, and (C) nighttime. The wind farm region is outlined in black, and, for reference, presently operational wind farms are shown as open circles in (A).

We tested horizontal resolution dependence by comparing the 10- and 30-km simulations with a turbine density of 3.0 MW km^{-2} with the respective 2012 controls. Differences in the annual average 2-m air temperature were small, as shown in Figure S1. The following results use a 30-km resolution (about one-ninth of the computational expense) and 2012, 2013, and 2014 simulation periods to reduce the influence of interannual variability. We use four turbine densities (0.5, 1.0, 1.5, and 3.0 MW km^{-2}) within the wind farm region to explore how increased wind power extraction rates alter the climatic impacts.

RESULTS AND DISCUSSION

Figure 1 shows the climate impacts of the benchmark scenario (0.5 MW km^{-2}). The wind farm region experiences warmer average temperatures (Figure 1A), with about twice the warming effect at night compared with during the day (Figures 1B and 1C). Warming was generally stronger nearer to the center of the wind farm region, but perhaps because teleconnections are suppressed by the forced boundary conditions. The climate response is concentrated in the wind farm region, but there are regions well outside the wind farm region also experiencing a climate response. The clearest example here is along the East Coast during the daytime, where average daytime temperatures are 0.1°C–0.5°C cooler (Figure 1B).

To separate the local direct boundary layer impacts from the mesoscale climate changes, we ran a diagnostic simulation with a 250 × 250-km ''hole'' near the center of the wind farm region, finding that the ''hole'' experienced about half the warming of the original ''no hole'' benchmark scenario during 2014 (Table S1 and Figure S2). This suggests that about half the warming effect is attributed to localized changes in atmospheric mixing, with the other half attributed to mesoscale changes, but this requires further study.

Changes in precipitation are small and show no clear spatial correlation (Figure S3). The warming is greatest in an N-S corridor near the center of the wind turbine array, perhaps because of an interaction between wind turbines and the nocturnal low-level jet (LLJ). The LLJ is a fast nocturnal low-altitude wind (>12 m s^{-1} at 0.5 km) common in the US Midwest, which occurs when the atmosphere decouples from surface friction, resulting in a steep vertical temperature gradient[35]—meteorological conditions that might be sensitive to perturbations by wind turbines. We quantified the presence of the LLJ in our control simulation but did not find a strong spatial correlation between the probability of LLJ occurrence and the nighttime warming (Figure S4). To explore mechanisms, we examine the vertical temperature gradient, atmospheric dissipation, and wind speed (Figure S5), and then explore the relationship between warming and these variables using scatterplots (Figure S6). We find some consistency between the dissipation rate of the control and the warming effect of wind turbines, but the correlation is weak.

Figure 2 explores the relationship between changes in vertical temperature gradient, atmospheric dissipation, and the simulated warming. Wind turbines reduce vertical gradients by mixing. During the day, vertical temperature gradients near the surface are small due to solar-driven convection and are only slightly reduced by the turbines. Gradients are larger at night, particularly during summer, and the gradient reduction caused by turbine-induced mixing is larger. The largest warming occurs when the reduction in gradient is strongest and the proportional increase in TKE is largest.

Warming and power generation saturate with increasing turbine density (Figure 3). The temperature saturation is sharper, so the ratio of temperature change per unit energy generation decreases with increasing turbine density. This suggests that wind's climate impacts per unit energy generation may be somewhat larger for lower values of total wind power production.

Power generation appears to approach the wind power generation limit at turbine densities somewhat above the maximum (3.0 MW km^{-2}) we explored. A capacity density of 1.5 MW_i km^{-2} roughly matches that of US wind farms installed in 2016,[36] and that simulation's power density of 0.46 W_e m^{-2} is very close to the 0.50 W_e m^{-2} observed for US wind farms during 2016.[36] The highest turbine density yields an areal (surface) power density of 0.70 W_e m^{-2}, consistent with some previous studies,[15,22,24,26,33] but half the 1.4 W_e m^{-2} assumed possible by 2050 from the same 3.0 MW km^{-2} turbine density into windy regions by the DOE.[28] While we did not compute a maximum wind power generation rate here, extrapolation of

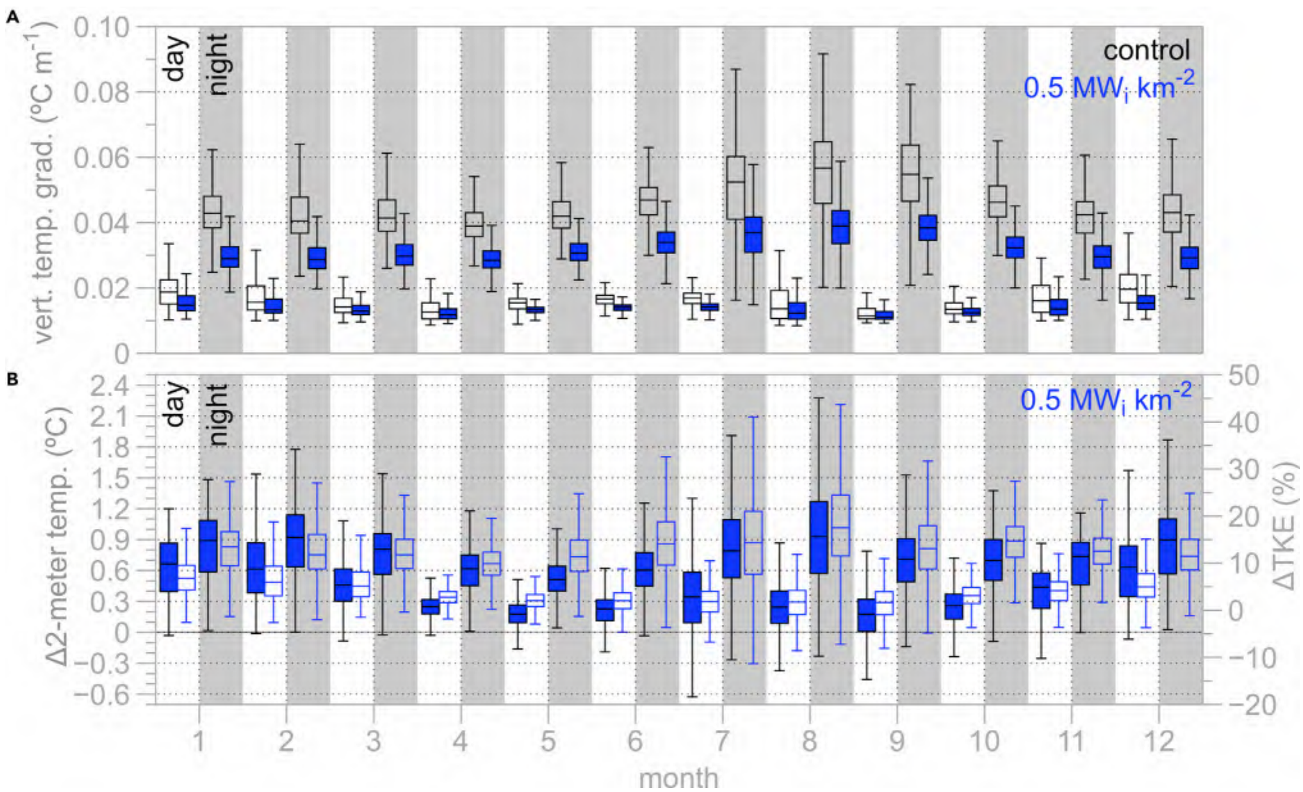

Figure 2. Monthly Day-Night Climate Response to the Benchmark Scenario

(A and B) Average monthly day and night values over the wind farm region for (A) vertical temperature gradient between the lowest two model levels (0–56 and 56–129 m) for the control and benchmark scenario (0.5 MW_i km^{-2}), and (B) differences between the benchmark scenario and control in 2-m air temperature (solid blue boxes) and turbulent kinetic energy (TKE) in the lowest model level (transparent boxes). In both, the vertical line extent shows the standard 1.5•interquartile range, and the box represents the 25th, 50th, and 75th percentiles.

Figure 3 suggests that it is about 2 TW_e, significantly less than the 3.7 TW_e of technical potential estimated by the DOE[28,29] over less land area. Clearly, interactions of wind turbines with climate must be considered in estimates of technical wind power potential.

Interpretation

The climatic impacts of wind power may be unexpected, as wind turbines only redistribute heat within the atmosphere, and the 1.0 W m^{-2} of heating resulting from kinetic energy dissipation in the lower atmosphere is only about 0.6% of the diurnally averaged radiative flux. But wind's climatic impacts are not caused by additional heating from the increased dissipation of kinetic energy. Impacts arise because turbine-atmosphere interactions alter surface-atmosphere fluxes, inducing climatic impacts that may be much larger than the direct impact of the dissipation alone.

As wind turbines extract kinetic energy from the atmospheric flow and slow wind speeds, the vertical gradient in wind speed steepens, and downward entrainment increases.[15] These interactions increase the mixing between air from above and air near the surface. The strength of these interactions depends on the meteorology and, in particular, the diurnal cycle of the ABL.

During the daytime, solar-driven convection mixes the atmosphere to heights of 1–3 km.[35]

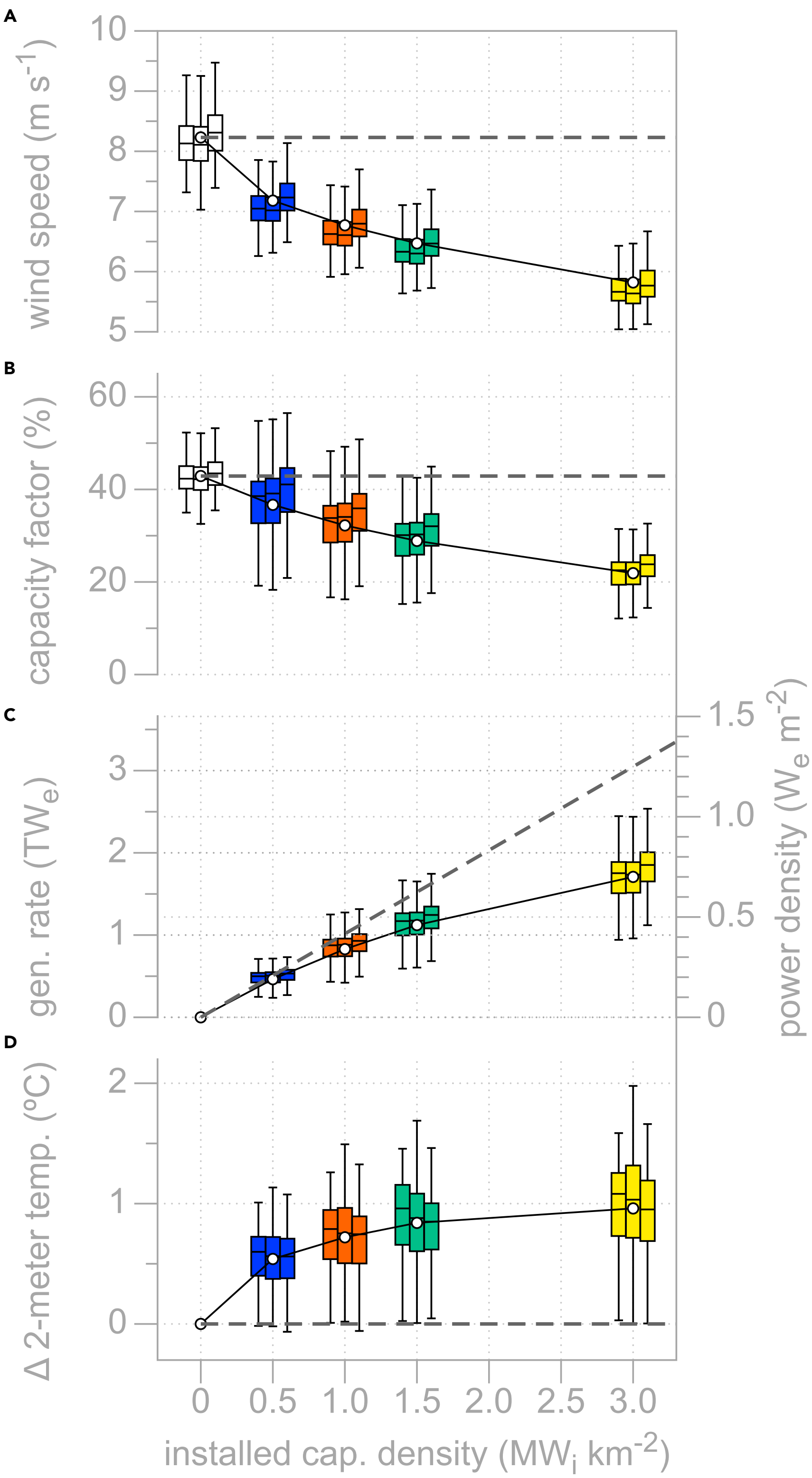

Figure 3. Variation in Mean Response to Changes in Installed Capacity Density

(A–D) The shared x axis is the installed electrical generation capacity per unit area. All values are averages over the wind farm region. (A) Eighty-four-meter hub-height wind speed, (B) capacity

Figure 3. *Continued*

factor, i.e., the ratio of realized electrical output to generation capacity, (C) power output as a sum and per unit area, and (D) difference in 2-m air temperature. For each value, three distinct years of data (2012–2014 from left to right) are shown as three boxplots (1.5•interquartile range, with 25th, 50th, and 75th percentiles). Colors help group identical installed capacity densities. The 3-year mean is shown using white points and connecting solid lines. Dashed lines illustrate the expected results if climate did not respond to the deployment of wind turbines.

Wind turbines operating during the daytime are enveloped within this already well-mixed air, so climatic impacts such as daytime temperature differences are generally quite small. At night, radiative cooling results in more stable surface conditions, with about 100–300 m of stable air separating the influence of surface friction from the winds aloft.[35] Wind turbines operating at night, with physical extents of 100–150 m and an influence height at night reaching 500 m or more,[15] can entrain warmer (potential temperature) air from above down into the previously stable and cooler (potential temperature) air near the surface, warming surface temperatures. In addition to the direct mixing by the turbine wakes, turbines reduce the wind speed gradient below their rotors and thus sharpen the gradient aloft. This sharp gradient may then generate additional turbulence and vertical mixing.

This explanation is broadly consistent with the strong day-night contrast of our benchmark scenario (Figures 1B and 1C). Within the wind farm region during the day, most locations experience warmer air temperatures, although ∼15% of locations show a daytime cooling effect in July-September. At night during July-September, less than 5% of locations show a cooling effect, and the warming effect at night over all months is much larger than during the daytime. This daytime and nighttime warming effect is also larger with higher turbine densities (Figure S7). Finally, the temperature perturbation in the benchmark scenario shows a strong correlation to differences in TKE within the lowest model level from 0 to 56 m (Figure 2B), with these increases in TKE downwind of turbines previously observed in Iowa[4] and offshore Germany,[37] and supporting our explanation that the temperature response is driven by increased vertical mixing (Figure 2).

Observational Evidence of Climatic Impacts

While numerous observational studies have linked wind power to reduced wind speeds and increased turbulence in the turbine wakes,[1,4,7,38,39] ten studies have quantified the climatic impacts resulting from these changes (Table 1).

Three ground-based studies have measured differences in surface temperature[1,5,7] and evaporation.[5] Generally, these ground-based observations show minimal climatic impacts during the day, but increased temperatures and evaporation rates at night.

Seven satellite-based studies have quantified surface (skin) temperature differences. By either comparing time periods before and after turbine deployment, or by comparing areas upwind, inside, and downwind of turbines, the spatial extent and intensity of warming for 28 operational wind farms in California,[40] Illinois,[6] Iowa,[2] and Texas[8–10] has been observed. There is substantial consistency between these satellite observations despite the diversity of local meteorology and wind farm deployment scales. Daytime temperature differences were small and slightly warmer and cooler, while nighttime temperature differences were larger and almost always warmer (Table 1). Interpretation of the satellite data is frustrated by fixed overpass times and clouds that sometimes obscure the surface.

Table 1. Overview of Observational Studies Linking Air Temperature Differences to Wind Farms

Reference	SAT or GND	Period	State	Notes: Climatic Impacts within or Very near to the Operational Wind Farm
Baidya Roy and Traiteur,[1] 2010	GND	53 days	CA	summer; ~1°C increase in 5-m air temperature downwind at night through the early morning; slight cooling effect during the day
Walsh-Thomas et al.[40] 2012	SAT	–	CA	~2°C warmer skin temperatures extending to about 2 km downwind, with visible temperature differences to 12 km downwind
Zhou et al.[9] 2012	SAT	9 years	TX	JJA night = +0.72°C, DJF night = +0.46°C; JJA day = −0.04°C; DJF day = +0.23°C; warming is spatially consistent with the arrangement of wind turbines
Zhou et al.[10] 2013	SAT	6 years	TX	QA1 values: DJF night = +0.22°C, MAM night = +0.29°C, JJA night = +0.35°C, SON night = 0.40°C, DJF day = +0.11°C, MAM day = −0.11°C, JJA day = +0.17°C, SON day = −0.04°C
Zhou et al.[10] 2013	SAT	2 years	TX	QA1 values: DJF night = −0.01°C, MAM night = +0.42°C, JJA night = +0.67°C, SON night = 0.47°C, DJF day = +0.14°C, MAM day = −0.42°C, JJA day = +1.52°C, SON day = +0.12°C
Xia et al.[8] 2016	SAT	7 years	TX	DJF night = +0.26°C, MAM night = +0.40°C, JJA night = +0.42°C, SON night = +0.27°C, Annual night = +0.31°C, DJF day = +0.18°C, MAM day = −0.25°C, JJA day = −0.26°C, SON day = −0.02°C, Annual day = −0.09°C
Harris et al.[2] 2014	SAT	11 years	IA	MAM night = +0.07°C, JJA night = +0.17°C, SON night = +0.15°C
Rajewski et al.[4] 2013	GND	122 days	IA	along the edge of a large wind farm directly downwind of ~13 turbines; generally cooler temperatures (0.07°C) with daytime periods that were 0.75°C cooler and nighttime periods that were 1.0–1.5°C warmer
Rajewski et al.[5] 2014	GND	122 days	IA	along the edge of a large wind farm downwind of ~13 turbines co-located with corn and soybeans; night-sensible heat flux and CO_2 respiration increase 1.5–2 times and wind speeds decrease by 25%–50%; daytime H_2O and CO_2 fluxes increase 5-fold 3–5 diameters downwind
Slawsky et al.[6] 2015	SAT	11 years	IL	DJF night = +0.39°C, MAM night = +0.27°C, JJA night = +0.18°C, SON = +0.26°C; Annual = +0.26°C
Smith et al.[7] 2013	GND	47 days	confidential	Spring; nighttime warming of 1.9°C downwind of a ~300 turbine wind farm

SAT, satellite-based observations; GND, ground-based observations. Note that measurements identified as the same state were completed over the same wind farms.

Although our benchmark scenario is very different in scale and turbine placement compared with operational wind power, it is nevertheless instructive to compare our simulation with observations. We compare results at a single Texas location (100.2°W, 32.3°N) where one of the world's largest clusters of operational wind turbines (~200 km^2, consisting of open space and patchy turbine densities of 3.8–4.7 MW km^{-2})[41] has been linked to differences in surface temperature in 3 of the observational studies in Table 1. Weighting the observations by the number of observed-years, the Texas location is 0.01°C warmer during the day and 0.29°C warmer at night (data in Table S2). Our benchmark scenario with a uniform turbine density of 0.5 MW km^{-2} at this location is 0.33°C warmer during the day and 0.66°C warmer at night. To explore the quantitative correlation between the seasonal and diurnal response, we take the 8 seasonal day and night values as independent pairs (Table S2), and find that the observations and the simulations are strongly correlated (Figure 4). This agreement provides strong evidence that the physical mechanisms being modified by the deployment of wind turbines are being captured by our model. This mechanism could be tested more directly if temperature observations upwind and downwind of a large turbine array were available at a high temporal resolution (<3 hr).

Limitations of Model Framework

Climate response is partly related to the choice and placement of wind turbine(s). We modeled a specific 3.0-MW turbine, but future deployment may shift to wind turbines with taller hub heights and larger rotor diameters. We also assumed

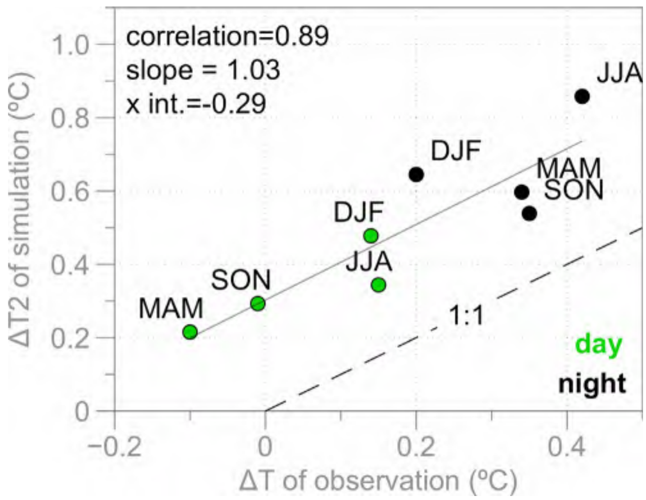

Figure 4. Comparison of Observations and Simulations for the Texas Location (Table 1)
We compare day and night response over four seasons. Observations are surface (skin) temperature differences. Simulation is differences in 2-m air temperatures between the benchmark scenario (0.5 MW km^{-2}) and control. Note that while correlation over eight points is high, the simulated response is larger, likely due to the much larger perturbed area and the difference between skin and 2 m air temperature.

that turbines were evenly spaced over the wind farm region, but real turbine deployment is patchier, potentially also altering turbine-atmosphere-surface interactions.

The model's boundary conditions are prescribed and do not respond to changes caused by wind turbines. Yet prior work has established that non-local climate responses to wind power may be significant,[12] suggesting that simulating our benchmark scenario with a global model (no boundary conditions restoring results to climatology) would allow possible climatic impacts outside the US to be assessed. Removal of the boundary conditions might also increase the warming in the wind farm region. The 3-year simulation period was also completed in 1-year blocks, so we do not simulate the response of longer-term climate dynamics influenced by variables such as soil moisture. Finally, model resolution influenced the estimated climatic impacts. Simulations with a 10-km horizontal resolution and the highest turbine density of 3.0 MW km^{-2} caused 18% less warming than the 30-km simulation (+0.80°C and +0.98°C). Simulations using a global model with an unequally spaced grid with high-resolution over the US could resolve some of these uncertainties.

Comparing Climatic Impacts to Climatic Benefits

Environmental impacts of energy technologies are often compared per unit energy production.[42] Because a central benefit of low-carbon energies like wind and solar is reduced climate change, dimensionless climate-to-climatic comparisons between the climate impacts and climate benefits of reduced emissions are relevant for public policy.

Climate impacts will, of course, depend on a range of climate variables that would need to be examined in a comprehensive impact assessment. In this analysis we nevertheless use 2-m air temperature as a single metric of climate change given (1) that there are important direct impacts of temperature, (2) that temperature change is strongly correlated with other important climate variables, and (3) that use of temperature as a proxy for other impacts is commonplace in climate impacts assessments. Limitations and caveats of our analysis are addressed in the following sub-section.

When wind (or solar) power replace fossil energy, they cut CO_2 emissions, reducing GHG-driven global climate change, while at the same time causing climatic impacts as described above and elsewhere.[1–15,22–26,34,40,43–45] The climatic impacts differ in (at least) two important dimensions. First, the direct climatic impact of wind power is immediate but would disappear if the turbines were removed, while the climatic benefits of reducing emissions grows with the cumulative reduction in emissions and persists for millennia. Second, the direct climatic impacts of wind power are predominantly local to the wind farm region, while the benefits of reduced emissions are global. We revisit and elaborate these differences in a systematic list of caveats at the end of this subsection.

As a step toward a climate-impact to climate-benefit comparison for wind, we compare warming over the US. We begin by assuming that US wind power generation increases linearly from the current level to 0.46 TW_e in 2080 and is constant thereafter. We estimate the associated warming by scaling our benchmark scenario's temperature differences linearly with wind power generation. The amount of avoided emissions—and thus the climate benefit—depends on the emissions intensity of the electricity that wind displaces. We bracket uncertainties in the time evolution of the carbon-intensity of US electric power generation in the absence of wind power by using two pathways. One pathway assumes a static emissions intensity at the 2016 value (0.44 $kgCO_2\ kWh^{-1}$), while the second pathway's emissions intensity decreases linearly to zero at 2100, which is roughly consistent with the GCAM model[46] that meets the IPCC RCP4.5 scenario. The two emissions pathways are then reduced by the (zero emission) wind power generation rate at that time (Figure 5C). The first pathway likely exaggerates wind power's emission reductions, while the second reflects reduced climate-benefit for wind in a transition to a zero-carbon grid that might be powered by solar or nuclear.

It is implausible that the US would make deep emissions cuts while the rest of the world continues with business-as-usual, so we include a third pathway, which functions just like the first pathway, except that the global (rather than just US) electricity emissions intensity declines to zero (Figure S8)

We estimate wind's reduction in global warming by applying the two US and one global emission pathways to an emissions-to-climate impulse response function.[47] We convert these global results to a US warming estimate using the 1.34:1 ratio of US-to-global warming from IPCC RCP4.5 and RCP8.5 ensemble means (Figure S9,[48]).

The benchmark scenario's warming of 0.24°C over the Continental US and 0.54°C over the wind farm region are small-to-large depending on the baseline. Climatic impacts are small if compared with US temperature projections— historical and ongoing global emissions are projected to cause the Continental US to be 0.24°C warmer than today by the year 2030 (Figure S8). Assuming emissions cuts are implemented globally, then the climatic impacts of wind power affecting the US in 2100 are approximately equivalent to the avoided warming from reduced global emissions (green region of Figure 5D). Climatic impacts are large if the US is the only country reducing emissions over this century (blue and gray shaded regions of

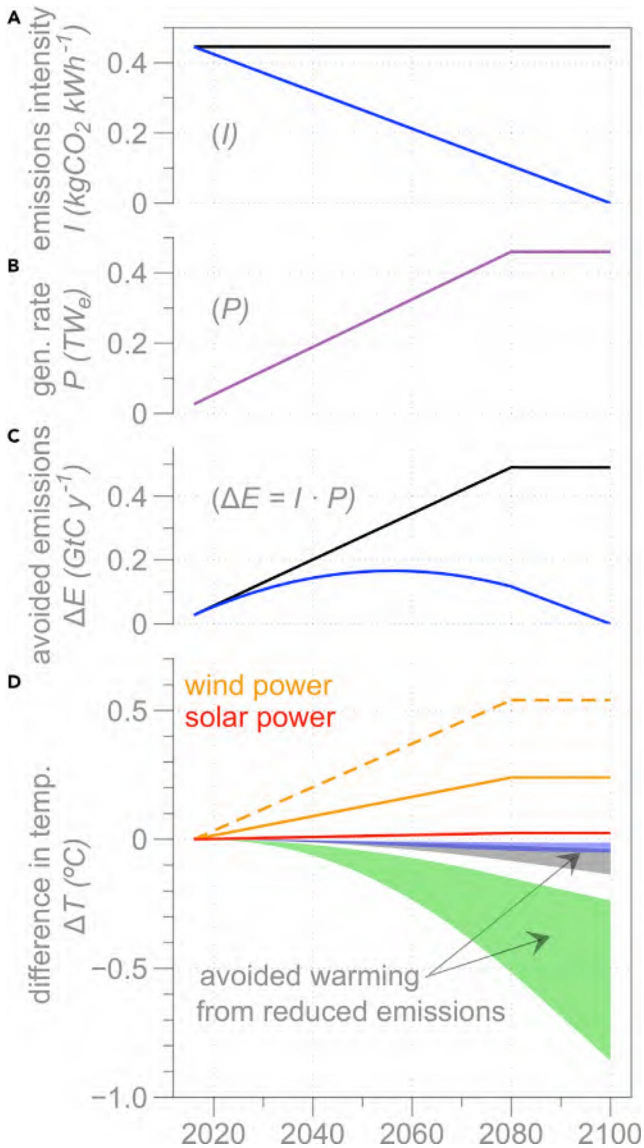

Figure 5. Climate Warming Impacts Compared to Climate Benefits of Reduced Emissions

(A) Two US scenarios, static (black) and declining (blue) emissions intensity, *I*, from US electric power.

(B) A scenario in which power output, *P*, from wind or solar power increases to our benchmark scenario's 0.46 TWe by 2080.

(C and D) Avoided emissions computed as $\Delta E = I \times P$ (C) and the resulting 2-m temperature differences within the wind farm region (dotted lines) and the Continental US (solid lines) (D). Values for wind power linearly scaled from our benchmark scenario, while values for solar power are derived from Nemet.[18] For comparison, the avoided warming of the Continental US from reduced emissions is shown for the static US scenario (gray) and the declining US scenario (blue). The green area shows the avoided warming of the Continental US if global electricity emissions were zero by 2080. The range of avoided warming for each pathway is estimated from the min and max values within the emissions-to-climate impulse response function.

Figure 5D). Timescale matters because climatic impacts are immediate, while climate benefits grow slowly with accumulated emission reductions. The longer the time horizon, the less important wind power's impacts are compared with its benefits (Box 1).

Box 1. Limitations of Using these Results to Compare the Climatic Impacts of Wind Power to Climate Change from Long-Lived Greenhouse Gases

The comparison above suggests that if US electricity demand was met with US-based wind power, the wind farm array would need to operate for more than a century before the warming effect over the Continental US caused by turbine-atmosphere interactions would be smaller than the reduced warming effect from lowering emissions. This conclusion is subject to a number of caveats including:

- Fundamentally different mechanisms cause warmer temperatures from climate change compared with wind power. Increased GHG concentrations reduce radiative heat losses to space, trapping more heat in the atmosphere and causing warmer surface temperatures. Wind power does not add more heat to the atmosphere—wind turbines redistribute heat by mixing and alter large-scale flows both which can change climate.
- Our comparison was based solely on surface air temperature differences. Wind turbines and GHGs both alter a host of interrelated climate variables. The use of surface temperature as the sole proxy for climate impacts may bias the resulting ratio of impacts-to-benefits in either direction.
- Climate impacts of the benchmark scenario will likely be larger and more widespread if we did not use forced boundary conditions, which prevents any feedbacks from the large-scale circulation.
- Results depend on the wind electricity generation rate, consistent with previous work.[11] Our results (Figure 3) suggest the temperature response is *roughly* linear to the generation rate and power density. To the extent that we see deviations from linearity (Figure S7), climate impacts per unit generation are larger for lower turbine densities.
- Results depend on the spatial distribution and density of wind turbines. We assumed that the windiest areas would be exploited and that developers would use low turbine densities to maximize per-turbine generation. Based on simulated results with higher turbine densities (Figure 3), doubling the turbine density over an area half as large as the benchmark scenario might generate almost the same power as the benchmark scenario, while increasing warming over this smaller region by only about a third.
- Our comparison metric ignores many possible benefits and drawbacks of the climate impacts caused by wind power deployment, including:
  - Arctic cooling shown in most large-scale wind power modeling studies.[11,23,24,45]
  - Warmer minimum daily temperatures reduce the incidence and severity of frost, and lengthen the growing season. Compared to the control, the growing season of the wind farm region was 8 days longer in our benchmark scenario, and 13 days longer with 3.0 $MW_i\ km^{-2}$.
  - Some locations experience cooler average temperatures during the summer (Figure 2B), consistent with observations,[1,4] and could reduce heat stress.
  - Warmer minimum daily temperatures have been observed to reduce crop yield.[49]
  - Warmer minimum temperatures could influence insect life history in unknown ways.[50]
- The comparison depends on area-weighting. We used equal weighting but one could consider weighting by, for example, population or agricultural production.
- The comparison depends very strongly on the time horizon. We examined the century timescale consistent with Global Warming Potentials, but there is no single right answer for time discounting.[51,52]
- Finally, results depend on the comparison of US and global-scale impacts and benefits: our model framework prevents global-scale analyses, but, assuming a substantial fraction of the warming effect occurred where US wind turbines were operating, global area-weighted benefits would offset the climatic impacts sooner than if impacts and benefits were quantified over just the US (as done here).

Implications for Energy System Decarbonization

Wind beats fossil fuels under any reasonable measure of long-term environmental impacts per unit of energy generated. Assessing the environmental impacts of wind power is relevant because, like all energy sources, wind power causes climatic impacts. As society decarbonizes energy systems to limit climate change, policy makers will confront trade-offs between various low-carbon energy technologies such as wind, solar, biofuels, nuclear, and fossil fuels with carbon capture. Each technology benefits the global climate by reducing carbon emissions, but each also causes local environmental impacts.

Our analysis allows a simple comparison of wind power's climate benefits and impacts at the continental scale. As wind and solar are rapidly growing sources of low-carbon electricity, we compare the climate benefit-to-impact ratio of wind and solar power.

The climate impacts of solar PVs arise from changes in solar absorption (albedo). A prior study estimated that radiative forcing per unit generation increased at 0.9 $mWm^{-2}/TW_{e,}$ in a scenario in which module efficiency reaches 28% in 2100 with installations over 20% rooftops, 40% grasslands, and 40% deserts.[18] Assuming that the climatic impact is localized to the deployment area and using a climate sensitivity of 0.8K/Wm^{-2},[53] generating 0.46 TW_e of solar PVs would warm the Continental US by 0.024°C. This warming effect is 10-times smaller than wind's (0.24°C, Figure 5D) for the same energy generation rate. This contrast is linked to differences in power density and thus to the areal footprint per unit energy—US solar farms presently generate about 5.4 W_e m^{-2}, while US wind farms generate about 0.5 W_e m^{-2}.[36] We speculate that solar PVs' climatic impacts might be reduced by choosing low albedo sites to reduce impacts or by altering the spectral reflectivity of panels. Reducing wind's climatic impacts may be more difficult, but might be altered by increasing the height of the turbine rotor above the surface distance to reduce interactions between the turbulent wake and the ground, or switching the turbines on or off depending on meteorological conditions.

In agreement with observations and prior model-based analyses, US wind power will likely cause non-negligible climate impacts. While these impacts differ from the climate impacts of GHGs in many important respects, they should not be neglected. Wind's climate impacts are large compared with solar PVs. Similar studies are needed for offshore wind power, for other countries, and for other renewable technologies. There is no simple answer regarding the *best* renewable technology, but choices between renewable energy sources should be informed by systematic analysis of their generation potential and their environmental impacts.

SUPPLEMENTAL INFORMATION

Supplemental Information includes nine figures and two tables and can be found with this article online at https://doi.org/10.1016/j.joule.2018.09.009.

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AUTHOR CONTRIBUTIONS

Conceptualization, L.M.M. and D.W.K.; Methodology, L.M.M.; Investigation, L.M.M. and D.W.K.; Writing – Original Draft, L.M.M. and D.W.K.; Writing – Review & Editing, L.M.M. and D.W.K.; Visualization, L.M.M. and D.W.K.; Funding Acquisition, D.W.K.

DECLARATION OF INTERESTS

D.W.K. is an employee, shareholder, and executive board member at Carbon Engineering (Squamish, BC). Carbon Engineering is developing renewable electricity to fuels projects and is developing procurement contracts for wind and solar power.

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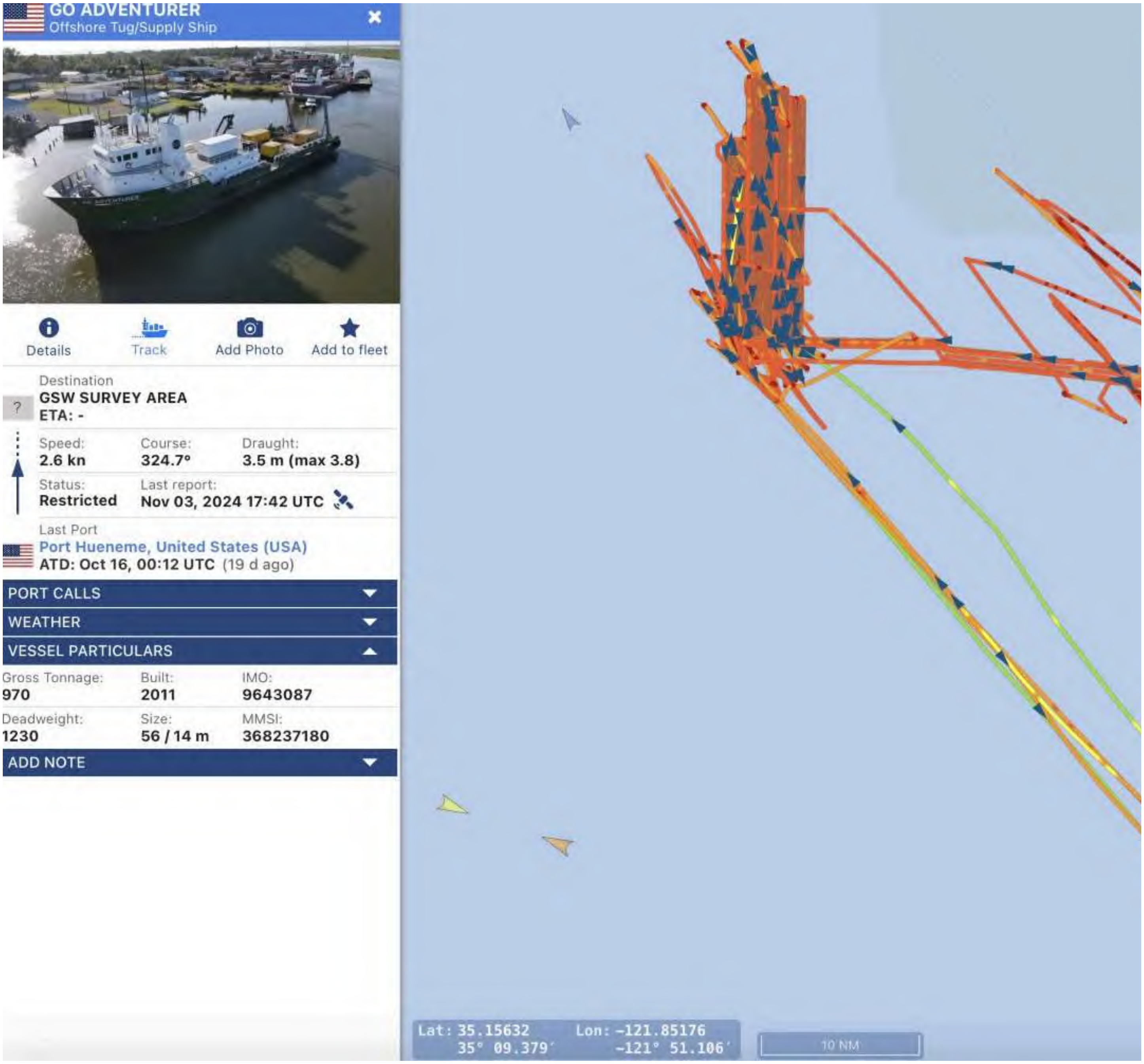
Outlook

Golden State Wind's plan to do HRG mapping of large swaths of the ocean for cable routes including areas to Point Buchon. Please add to administrative records

From mbcfo member <[redacted]>
Date Sun 11/03/2024 10:23 AM
To Doug Boren <douglas.boren@boem.gov>; John Romero <john.romero@boem.gov>; Andrea Chmelik <Andrea.Chmelik@asm.ca.gov>; Dobroski, Nicole@SLC <Nicole.Dobroski@slc.ca.gov>; FGC <FGC@fgc.ca.gov>; Flint, Scott@Energy <Scott.Flint@energy.ca.gov>; bgibson@co.slo.ca.us <bgibson@co.slo.ca.us>; Debbie Arnold <debbie@debbieforslo.com>; Greg Haas <greg.haas@mail.house.gov>; Harland, Eli@Energy <Eli.Harland@energy.ca.gov>; Zara Landrum <zlandrum@morrobayca.gov>; Lucchesi, Jennifer@SLC <Jennifer.Lucchesi@slc.ca.gov>; Mattox, Jennifer@SLC <Jennifer.Mattox@slc.ca.gov>; Miller-Henson, Melissa [redacted]>; Michael Milstein <michael.milstein@noaa.gov>; Norway Embassy in Washington DC <emb.washington@mfa.no>; Payne, Elizabeth@Waterboards <Elizabeth.Payne@waterboards.ca.gov>; Reece, Elizabeth@Waterboards <Elizabeth.Reece@Waterboards.ca.gov>; Suzy Watkins <suzyw@portsanluis.com>; Clint Weirick <clint.weirick@sen.ca.gov>
Cc Paloma Aquirre <Paloma.Aguirre@coastal.ca.gov>; Dayna Bochco <Dayna.Bochco@coastal.ca.gov>; Raul Campillo <raul.campillo@coastal.ca.gov>; Justin Cummings <Justin.Cummings@coastal.ca.gov>; Linda Escalante <Linda.Escalante@coastal.ca.gov>; Meagan Harmon <Meagan.Harmon@coastal.ca.gov>; Dr. Caryl Hart <Caryl.Hart@coastal.ca.gov>; Susan Lowenberg <Susan.Lowenberg@coastal.ca.gov>; Ann Notthoff <Ann.Notthoff@coastal.ca.gov>; Katie Rice <Katie.Rice@coastal.ca.gov>; Charles Striplen <charles.striplen@coastal.ca.gov>; Effie Turnbull-Sanders <Effie.Turnbull-Sanders@coastal.ca.gov>; Roberto Uranga <Roberto.Uranga@coastal.ca.gov>; Mike Wilson <mike.wilson@coastal.ca.gov>; Wyer, Holly@Coastal <holly.wyer@coastal.ca.gov>; Huckelbridge, Kate@Coastal <Kate.Huckelbridge@coastal.ca.gov>

Here are the plans sent to us for High Resolution Survey mapping October thru December for cable routes. Note that it includes a very large swath of area including areas around Point Buchon MPA. The California Coastal Commission has already not allowed Atlas Wind to do HRG survey work around the Pt. Buchon MPA. Is this allowed? Does the BOEM permit for the leased wind energy area also allow permission for all this area for the cables????

This is the satellite tracking of Golden State Wind's survey vessel as of 11/03/24. Note all the mapping between the Wind Energy Area and the 3 mile line.



Please show where this is permitted.

Sincerely,

Tom Hafer, President
[redacted]

GOLDEN STATE WIND

2024 Geophysical Surveys

What are Geophysical Surveys?

Geophysical surveys are non-intrusive and use low energy equipment to map the seafloor and the geological layers beneath it, and to identify archaeological resources. Information collected during surveys will be used to identify habitats and cultural resources (e.g. shipwrecks or marine archaeological resources) that may need to be avoided, and to determine the physical properties of the seabed to inform selection of the mooring system technology. Geophysical data is required to develop and submit a Construction and Operations Plan (COP) to the Bureau of Ocean Energy Management (BOEM).

What type of survey equipment will Golden State Wind use?

We will use industry standard low-energy survey technology that has been routinely used in surveys off the Central Coast. Geophysical surveys will be conducted using an autonomous underwater vehicle (AUV) that will operate approximately 10-20 meters above the seabed. The AUV is equipped with multibeam echosounders, side scan sonars, and sub bottom profilers that will map and create images of the seafloor and generate vertical cross sections of the sediment layers below the seafloor. This geophysical survey technology is very different from high energy seismic airguns used in oil and gas surveys or tactical military sonar, having lower noise, higher frequency, and narrower beamwidth.

What mitigation measures are used during marine surveys?

Golden State Wind is committed to conducting geophysical surveys in a safe, environmentally responsible manner, that complies with all applicable federal, state, and local regulations. Our surveys will comply with all conditions from the combined federal and state agency review which together include:

- Use of Protected Species Observers (PSOs) on vessels
- Use of monitoring and shutdown zones
- Limiting vessel speed to 10 knots
- Marine debris awareness training for vessel crew
- Use of low-energy geophysical survey equipment as defined in California State Regulation 2 CCR § 2100.03(g)

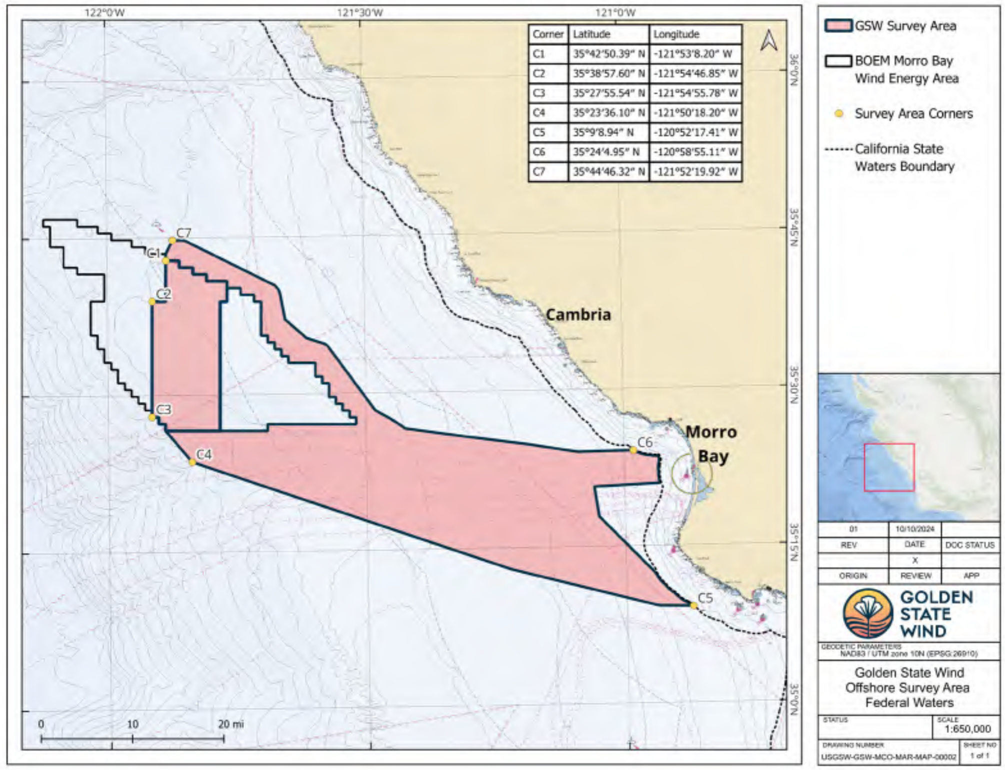
How will Golden State Wind communicate with fishermen and other ocean users?

Golden State Wind will implement measures to minimize conflict with other ocean users, such as commercial and recreational fisheries, as detailed in the project's Fisheries Communications Plan, which can be found on the project website. Golden State Wind will use the following methods to communicate about survey activities:

- A dedicated Fisheries Liaison responsible for outreach via email, phone, and texts
- USCG Local Notice to Mariners and Broadcast Notice to Mariners
- The survey vessel will be broadcasting AIS 24/7 for other ocean users' awareness
- At sea, communication with fishermen via VHF CH 13 and CH 16 and minimize conflict

Where and when will Golden State Wind be conducting offshore surveys?

Low-energy geophysical surveys will be conducted in federal waters through December 31, 2024. (see map)



What is the survey vessel information?

US Flagged ship: Go Adventurer

Length: 205 feet

Vessel description:
Green hull, white house

Port: Operating to and from Port Hueneme on an estimated 28-day cycle.

Call Sign: WDM7780

IMO: 9643087

MMSI: 368237180

What surveys will Golden State Wind conduct in the future?

Golden State Wind will conduct additional marine and terrestrial surveys to better understand environmental and socioeconomic resources to support design and permitting of the project. These will include marine benthic surveys, geotechnical surveys, cultural resources surveys, and ecological surveys. Golden State Wind is working with federal and state agencies to determine the surveys that will be needed for project permitting.

What permits and approvals were needed for Golden State Wind's Geophysical Surveys?

Geophysical surveys were reviewed and authorized in 2022 under the National Environmental Policy Act, the Coastal Zone Management Act, and California Coastal Act. All geophysical survey equipment will comply with applicable environmental regulations including recommendations and requirements from NOAA Fisheries' Endangered Species Act Section 7(a)(2) Concurrence Letter and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Bureau of Ocean Energy Management's Offshore Wind Lease Issuance, Site Characterization and Assessment for the Morro Bay and Humboldt Wind Energy Areas. Golden State Wind submitted a survey plan to BOEM and the California Coastal Commission for review. In May 2024, BOEM confirmed that all mandatory comments have been adequately addressed.

GOLDEN STATE WIND

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Outlook

Press release: Another windfarm surpasses £1 billion in subsidy payments

From mbcfo member <[redacted]>
Date Thu 11/14/2024 07:48 AM
To Debbie Arnold <debbie@debbieforslo.com>; Doug Boren <douglas.boren@boem.gov>; Andrea Chmelik <Andrea.Chmelik@asm.ca.gov>; Justin Cummings <Justin.Cummings@coastal.ca.gov>; Dobroski, Nicole@SLC <Nicole.Dobroski@slc.ca.gov>; FGC <FGC@fgc.ca.gov>; Flint, Scott@Energy <Scott.Flint@energy.ca.gov>; bgibson@co.slo.ca.us <bgibson@co.slo.ca.us>; Greg Haas <greg.haas@mail.house.gov>; Harland, Eli@Energy <Eli.Harland@energy.ca.gov>; Dr. Caryl Hart <Caryl.Hart@coastal.ca.gov>; Huckelbridge, Kate@Coastal <Kate.Huckelbridge@coastal.ca.gov>; Zara Landrum <zlandrum@morrobayca.gov>; Lucchesi, Jennifer@SLC <Jennifer.Lucchesi@slc.ca.gov>; Mattox, Jennifer@SLC <Jennifer.Mattox@slc.ca.gov>; Miller-Henson, Melissa [redacted]>; Michael Milstein <michael.milstein@noaa.gov>; Norway Embassy in Washington DC <emb.washington@mfa.no>; Payne, Elizabeth@Waterboards <Elizabeth.Payne@waterboards.ca.gov>; Reece, Elizabeth@Waterboards <Elizabeth.Reece@Waterboards.ca.gov>

https://www.netzerowatch.com/campaigns/view-email/d_uog1bHfXu1ELvuZQuDEhimSOwfERIZFMQqZksKJYmHPZB5b6cZJOMtEdS5AoZEcAPMgGXQ13rVrcS_XY7redXtcZ0j6W-qfR92d3BhYxY-P3XzNsauF58iiBJS-0MR0nXaA8XEaJWQsfJ3c2ydEpWlhA5Q4OFu-4E_aA==?ss_source=sscampaigns&ss_campaign_id=673611a5e3dfa015781c7e0f&ss_email_id=673614a1791ea5538f83ca63&ss_campaign_name=Press+release:+Another+windfarm+surpasses+£1+billion+in+subsidy+payments&ss_campaign_sent_date=2024-11-14T15:17:58Z

Tom Hafer, President
[redacted]

Press release: Another windfarm surpasses £1 billion in subsidy payments

The Beatrice Offshore Windfarm has become the fourth windfarm to have received more than £1 billion in subsidy payments. The landmark was reached in just its seventh year of operation, suggesting that it could reach £2 billion over the course of its subsidy agreement.

Beatrice, situated in the Moray Firth, cost £2.2 billion to construct. Thus consumer levies will pay for almost the entire cost of the windfarm. The profits are ultimately shared by SSE plc and the Danish investment house, Copenhagen Infrastructure Partners.

Net Zero Watch has condemned the waste. Its director Andrew Montford said:

> "This level of subsidy is obscene. The Westminster machine is hosing down the green lobby with our money. The consumer interest is nowhere to be seen."

Richard Tice, deputy leader of Reform UK said:

> "Renewable energy subsidies are making people poorer with higher bills. Businesses are less competitive, meaning less growth and fewer jobs. Reform would put a windfall tax on all renewables to the value of the subsidies. We need to copy the US plan and 'drill baby drill' to make people better off."

Notes for editors

1. The other windfarms that have received more than a billion pounds in subsidy are:

- Walney Extension £1.7bn
- Hornsea One £1.6 bn
- Dudgeon £1.2 bn

2. The CfD scheme as a whole has paid out a net £9.2 billion since 2016. Payments are now running at around £200 million per month.

3. The subsidy figure is revealed in data released by the Low Carbon Contracts Company.

Outlook

Offshore Wind impacts

From mbcfo member <[redacted]>

Date Fri 11/29/2024 08:35 AM

To Doug Boren <douglas.boren@boem.gov>; Andrea Chmelik <Andrea.Chmelik@asm.ca.gov>; Justin Cummings <Justin.Cummings@coastal.ca.gov>; Dobroski, Nicole@SLC <Nicole.Dobroski@slc.ca.gov>; FGC <FGC@fgc.ca.gov>; Flint, Scott@Energy <Scott.Flint@energy.ca.gov>; bgibson@co.slo.ca.us <bgibson@co.slo.ca.us>; Greg Haas <greg.haas@mail.house.gov>; Harland, Eli@Energy <Eli.Harland@energy.ca.gov>; Dr. Caryl Hart <Caryl.Hart@coastal.ca.gov>; Huckelbridge, Kate@Coastal <Kate.Huckelbridge@coastal.ca.gov>; Zara Landrum <zlandrum@morrobayca.gov>; Lucchesi, Jennifer@SLC <Jennifer.Lucchesi@slc.ca.gov>; Mattox, Jennifer@SLC <Jennifer.Mattox@slc.ca.gov>; Miller-Henson, Melissa [redacted]>; Michael Milstein <michael.milstein@noaa.gov>; Norway Embassy in Washington DC <emb.washington@mfa.no>; Payne, Elizabeth@Waterboards <Elizabeth.Payne@waterboards.ca.gov>; Reece, Elizabeth@Waterboards <Elizabeth.Reece@Waterboards.ca.gov>; John Romero <john.romero@boem.gov>

Good Morning,

Please add these reviews to your administrative records on the impacts from offshore wind farms.

Thank you,

Tom Hafer, President
[redacted]

Ecological impacts of the expansion of offshore wind farms on trophic level species of marine food chain

Highlights

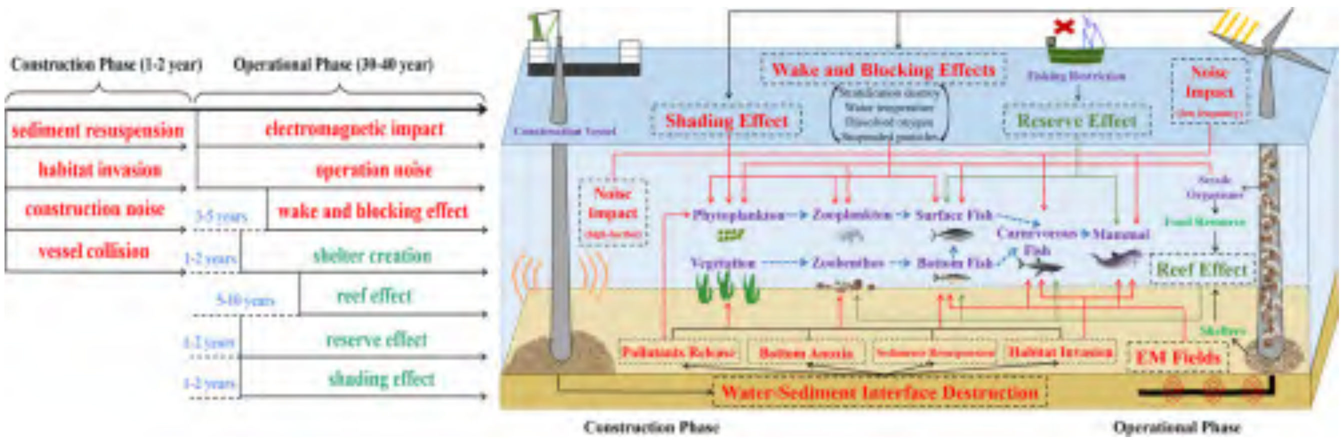
- Field data and simulated results were used to reveal ecological impacts of OWFs.
- OWFs have direct and indirect impacts on the marine species at each trophic level.
- Marine ecosystem evolves into more complex state due to OWFs installation.
- Ecological risk management and life-cycle-assessment of OWFs have been suggested.
- Carbon emission and deposition caused by OWFs in marine ecosystem should be assessed.

Abstract

The global demand for renewable energy has resulted in a rapid expansion of offshore wind farms (OWFs) and increased attention to the ecological impacts of OWFs on the marine ecosystem. Previous reviews mainly focused on the OWFs' impacts on individual species like birds, bats, or mammals. This review collected numerous field-measured data and simulated results to summarize the ecological impacts on phytoplankton, zooplankton, zoobenthos, fishes, and mammals from each trophic level and also analyze their interactions in the marine food chain. Phytoplankton and zooplankton are positively or adversely affected by the 'wave effect', 'shading effect', oxygen depletion and predation pressure, leading to *a* ± 10% fluctuation of primary production. Although zoobenthos are threatened transiently by habitat destruction with a reduction of around 60% in biomass in the construction stage, their abundance exhibited an over 90% increase, dominated by sessile species, due to the 'reef effect' in the operation stage. Marine fishes and mammals are to endure the interferences of noise and electromagnetic, but they are also aggregated around OWFs by the 'reef effect' and 'reserve effect'. Furthermore, the complexity of marine ecosystem would increase with a promotion of the total system biomass by 40% through trophic cascade effects strengthen and resource partitioning alternation triggered by the

proliferation of filter-feeders. The suitable site selection, long-term monitoring, and life-cycle-assessment of ecological impacts of OWFs that are lacking in current literature have been described in this review, as well as the carbon emission and deposition.

Graphical abstract



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- Next article in issue

Keywords

Offshore wind farms (OWFs)

Ecological impacts

Plankton

Benthos

Fish

Mammal

Introduction

Global-scale climate change and its links with non-renewable fossil fuels have led to an urgent demand for electricity generation from renewable resources (IEA, 2019; IRENA, 2020). A new focus on renewable green resources of wind and solar research and development arose to tackle the trend of climate warming in recent years (Eava et al., 2022). With high wind velocity, stable performance, large power generation, and negligible land occupation, offshore wind farms (OWFs) have become the core power source to promote the further achievement of global carbon-neutrality in many countries (Hernandez et al., 2014; Schuster et al., 2015). The amounts of offshore wind capacity have increased from 2.06 GW in 2010 to 54.94 GW by the end of June 2022 (IRENA, 2020; WFO, 2022), corresponding to 248 OWFs in service worldwide. However, the technical, legal, social, and environmental points of view are challenges for developers to construct OWFs (Batel and Susana, 2017; Maarten, 2018), especially for the ocean environment (Nyström et al., 2019). With the rapid development of OWFs, more and more artificial infrastructures have been integrated into the marine ecosystem, along with anthropogenic disturbance, including direct and/or indirect impacts on marine organisms and the ecosystem.

Until now, the ecological impacts on marine species and the ecosystem have almost focused on the construction and operation phases of OWFs in previous studies, which might depend on the fact that most OWFs are in service and few are decommissioned on a large scale. In fact, the ecological impacts during the construction and operation phases differed on marine species and ecosystems at and around the OWFs installations. Some direct and negative effects generally occur during the construction process of OWFs, such as sediment-water interface destruction, endogenous pollutants release, water stratification mixing, and high decibel noise disturbances (Dannheim et al., 2020; Gall et al., 2021). These drastic changes have led to numerous detrimental impacts, including disturbance of habitat and breeding places, changes in biomass and community composition, and disruption of signal communication and migration corridors on epibenthonic, benthonic organisms and plankton species in particular (De Mesel et al., 2015; Gaultier et al., 2020). Except for the negative impacts, OWFs also bring benefits to marine species through the "reef effect" and "reserve effect" in the operational phase, for instance in the form of new habitats, resting areas, and food resources (Inger et al., 2009; van Hal et al., 2017). Previous studies have also illustrated that due to OWF structures integration, the abundances of marine species are higher and the compositions of species communities are more diverse than that in the pre-construction stage, especially for an increase in the biomass and density of filter feeders and other fouling species (Lindeboom et al., 2011; Slavik et al., 2018). Meanwhile, the different community structures in different depth zones and food resource partitioning are the fundamental mechanisms allowing multiple species to co-existence in the vicinity of the turbine (Ross, 1986; Mavraki et al., 2020a). Furthermore, it is known that whether negative or positive impacts on every trophic level species would lead to changes in the interactions among the species in marine food chain. The ecological impacts of OWFs on some larger species, including sea birds, marine fishes, and mammals, have been almost demonstrated by investigating or simulating in some studies (Garthe et al., 2017; Van Hal et al., 2017; Eava et al., 2022). However, few reviews examined the variations of micro-organisms such as zoobenthos, zooplankton, and phytoplankton before and after OWFs construction (De Mesel et al., 2015; Causon and Gill, 2018). It is a fact that all changes in spatial distribution, community structure, and biomass of every trophic level species would influence on ecosystem stability, functioning and microcosmic matter, and energy transmission among different trophic levels within OWFs located in the sea area. Raoux et al. used the Ecopath model of food web flows and Ecosim simulation to predict impacts on the ecosystem structure and functioning over the next 30 years of the future OWFs that would be built in the bay of Seine (English Channel) (Raoux et al., 2019). Although the simulated results showed that the ecosystem was still in a healthy state due to the destruction degree by the OWFs construction did not exceed its overall resilience capacity, the authors emphasized the need to quantify the uncertain indices and understand multiple perturbations interaction between each other in order to produce robust conclusions and better prediction of OWFs disturbances (Raoux et al., 2017, 2019). Thus, the field-measured data are needed to reinforce the substantial impacts on the critical species of the marine food chain and interaction impacts among different trophic levels better to predict its consequences on ecosystem functioning and stability. There needs to be a holistic review to sum up the ecological impacts of OWFs on the species at different trophic levels and analyze their interactions within the regional-scale ecosystem of OWFs location.

In this review, we summarized the field-measured data and simulated modeling results of ecological impacts on the trophic level species from primary producers to top consumers of the marine food chain caused by OWFs installations worldwide. In order to systematically investigate the potential impacts on the marine food chain, this work took the typical biota of phytoplankton and vegetation, zooplankton, zoobenthos, fishes, and mammals at every trophic level as research objects to analyze the potential influencing paths and corresponding mechanisms caused by integrating into the marine ecosystem of OWFs. Moreover, the interactions among trophic level species were further analyzed. Finally, several ecological risk management and further developmental suggestions on how to deploy and select the suitable sites for OWFs construction, how to evaluate the ecological impacts of the different phases of OWFs, and how to assess carbon emission and deposition in a regional-scale ecosystem by OWFs deployment were discussed in details.

1. Review methodology

This review systematically investigated the potential environmental impacts of OWFs on the representative species at each trophic level. A comprehensive review usually consists of a detailed plan and search strategies based on the review question, the database, and inclusion or exclusion criteria on scientific information to screen relevant literature or reports (Paré et al., 2015; Pullin and Stewart, 2006). By explaining the formulated questions and generalizing relevant information, the conclusions from extensive scientific studies are available to be viewed and referenced by policymakers, managers, and researchers across disciplines.

1.1. Question formulation

Primary and secondary questions were proposed in the initial stage. The primary question was: '*Whether the construction and operation of OWFs lead to impacts on marine species at different trophic levels?*' This question was divided into several sections to receive more reliable conclusion in the final review. Secondary questions that focused on the central considerations of OWFs were established including: *What are the ecological impacts of OWFs on marine species? What are the potential influencing paths and corresponding mechanisms of OWFs' impacts on marine species? What are the interaction pathways among marine species caused by OWFs installation?*

1.2. Search strategy

In order to conduct an extensive literature review on related topics, the following databases were applied for the literature collection: standard literature search engines, including Google Scholar, Web of Science, and China National Knowledge Internet (CNKI). Additionally, to collect the latest data about the amount and cumulative capacity of OWFs in operation currently worldwide, the Global Offshore Wind Report by World Forum Offshore Wind (WFO) and the report from Global Wind Energy Council (GWEC) were analyzed.

1.3. Search terms

The strategies of keyword searches and citation chaining were used to identify relevant scientific information about the impacts of OWFs on marine species. The literature was relevant to the theme defined by the primary search terms, including 'environmental impacts or effects' and "offshore wind farm". Under these two keywords, 685 related literature was retrieved from the Web of Science database. Fig. 1 shows the distribution of publication years and research directions of that literature. More than 73% of them were published between 2015 and 2023, which were also the main target articles in this review. Besides peer-reviewed articles, published project reports and government reports were also available to reference. Furthermore, to get extensive peer-reviewed articles, the literature search was refined by several relevant subtopics with multiple keywords, like electromagnetic field, noise, collision, dynamics change, reef effect, wake effect, reserve effect, etc.

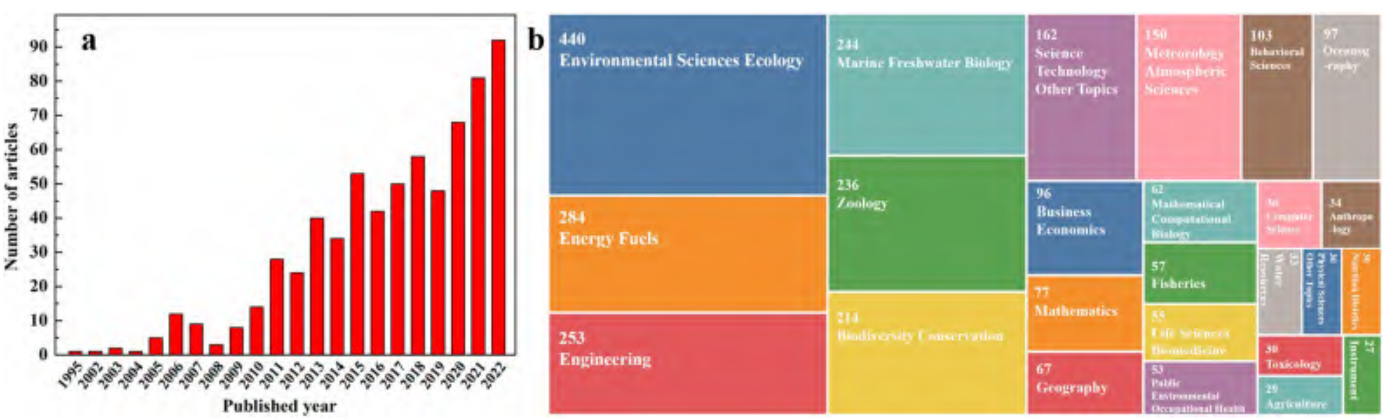

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Fig. 1. (a) Published years and (b) research directions of the retrieved results at Web of Science with the keywords of 'offshore wind farm' and

'environmental impacts'.

1.4. Analysis

In order to systematically summarize the impacts of OWFs on marine species, the target marine species at each trophic level were selected as follows: phytoplankton and vegetation-primary producers, zooplankton-primary consumers, zoobenthos-secondary consumers, fishes-tertiary consumers, and mammals-top consumers, respectively. A systematic qualitative review was then generated on the potential magnitude of the environmental impacts of OWFs. This review proposed an approach with the 'anthropogenic disturbance–stressor–receptor–impact–risk assessment' pathway to systematically summarize and conclude the relationships between OWFs and marine species. Furthermore, except for qualitative description, some certain quantitative comparisons of physicochemical parameters of seawater, species community, and biomass before and after OWFs operation were identified to support the qualitative descriptions. Case studies about the impacts of OWFs installation on the biomass or community composition alternations of plankton were also listed for further support.

2. Worldwide distribution of OWFs

Global OWFs installations experienced rapid growth recently.

Fig. 2 shows the distribution of the cumulative capacity of OWFs in operation before June 2022. China strengthens its position as the world's largest offshore wind market. During the half year of 2022, OWFs with a gross 5.1 GW capacity were newly installed in China, increasing its total installed capacity to 24.9 GW (WFO, 2022). UK and Germany have already become the second and third countries that owned OWFs in 2022, and the cumulative capacities were 13.6 GW and 7.7 GW, respectively (GWEC, 2022). In terms of regional difference, according to the Global Offshore Wind Report 2022, Europe occupied the largest offshore wind regional market, with 50.4% of total cumulative global offshore wind installations at the half year of 2022 and the cumulative capacities of grid-connected OWFs projects would surge to from 28.4 GW in 2022 to 450 GW before 2050 (Ramirez L, 2020). Asia shares the second highest market share (49.5%), and Asian markets largely drive global offshore wind growth. North America only accounted for 0.1% of total offshore wind installations outside Europe and Asia, with 42 MW offshore wind in operation (GWEC, 2022). Additionally, according to the number of OWFs connected, 248 OWFs are currently in operation, of which 134 are located in Asia, and 112 are located in Europe and the USA (project consisting of at least two offshore wind turbines) (WFO, 2022).

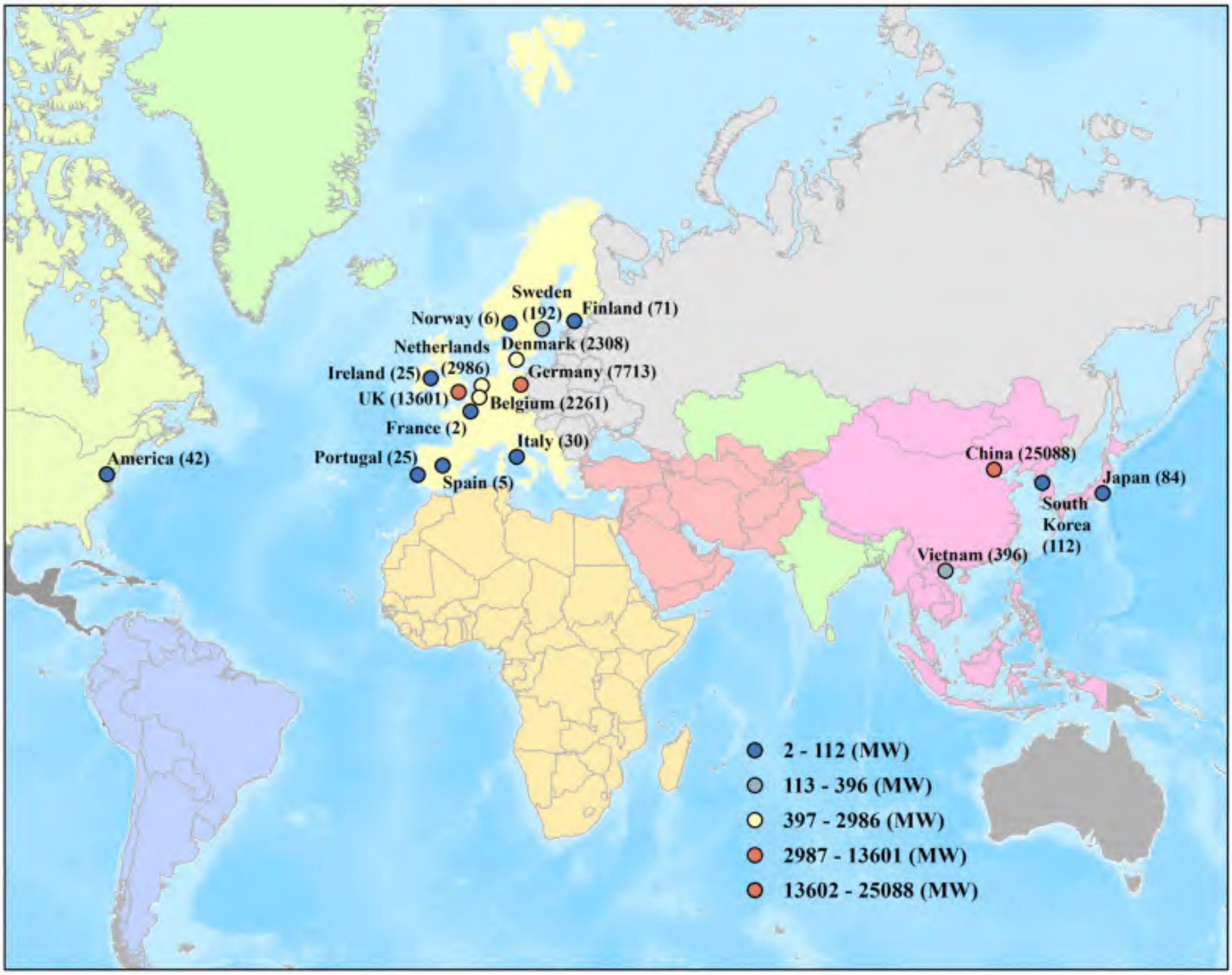

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Fig. 2. Cumulative capacity of offshore wind farm in operation (MW) (before June 2022).

3. Impacts on marine species at different trophic levels

3.1. Phytoplankton and vegetation - primary producer

3.1.1. Phytoplankton

Marine phytoplankton is micro-eukaryotes for the primary production of marine ecosystems with diverse, abundant, and cosmopolitan properties (Liu et al., 2022). Phytoplankton is so tiny with weak resistance that small changes in ambient conditions might result in significant impacts under anthropogenic interference. The construction of OWFs has been indicated to change marine phytoplankton's abundance and community structure (Fig. 3). Table 1 shows the changes in biomass, production, and consumption of phytoplankton communities after constructing OWFs through several simulated case studies.

(i)

Wake effect

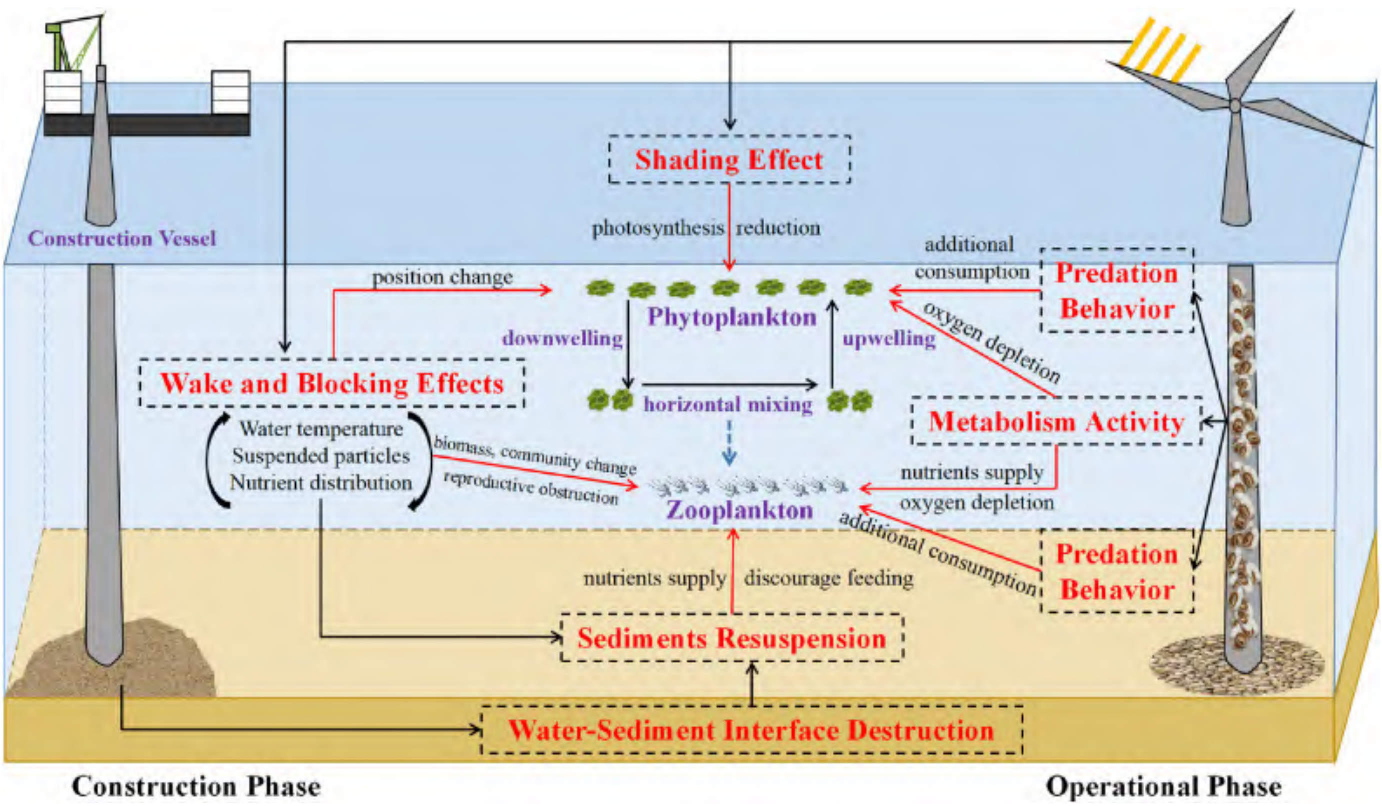

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Fig. 3. The ecological impacts on marine plankton (phytoplankton and zooplankton) by application with OWFs.

Table 1. Comparison of phytoplankton biomass before and after OWFs construction.

Location	Project stage	Biomass	P/B	C/B	EE
Rudong OWF, China (Simulated data)	Pre-construction	11.96 (ton/(km^2*year))	25.0	180	0.43
	Post-construction	14.85 (ton/(km^2*year))	25.0	195	0.44
Normandy, France (Simulated data)	Pre-construction	1.72 (g C/(m^2*year))	50.0	150	0.88
	Post-construction	1.79 (g C/(m^2*year))	47.4	141.8	0.99
Bay of Seine, English Channel (Simulated data)	Pre-construction	3.24 (g C/m^2)	–	–	0.76
	Post-construction	3.24 (g C/m^2)	–	–	0.99

Note: P/B: production/biomass; C/B: consumption/biomass; EE: ecotrophic efficiency; -: No available data.

The wake effect caused by the rotation of OWFs' propeller could reduce the wind speed downwind of the turbines over 15 km away from the farm (Hasager et al., 2017). The combinations of this anthropogenic mixing and the blocking effect of foundations on tidal currents would alter ocean hydrodynamics and stratification pattern, slow down circulation, and reduce bottom shear stress (Paskyabi and Fer, 2012; van der Molen et al., 2014), particularly during late spring and summer (Dorrell et al., 2022). The hydrodynamics properties in Laizhou Bay also monitored a noticeable flow velocity change (over 0.01 m/sec) within 0–150 m range of the pile foundations (Zhang et al., 2020b). The resulting water stratification damage, even a slight reduction in water column stability, was indicated to trigger algae blooms (Carpenter et al., 2016; Taylor, 2016). The potential implication might be that water mixing enhances nutrient influx into the euphotic zone from submarine sediments (Floeter et al., 2017; Lévy et al., 2001). Wang et al. (2019) calculated the production/biomass values of phytoplankton and found an increase from 106 to 150 after OWFs construction, indicating that phytoplankton obtained extra nutrients by resuspending sediments (Table 1). Except for the hydrodynamics changes, the water quality, including turbidity, water temperature, nutrient distribution, and salinity, which are the essential growth-affecting factors for phytoplankton would experience alterations due to the vertical mixing promotion (Rennau et al., 2012; Hasager et al., 2017). Wang et al. (2018) found that after a period time of OWFs operation, the abundance of phytoplankton was about 30 times higher than before construction in the Rudong coastal area of China, and this propagation of phytoplankton was positively correlated with the increased suspended solids in water ($P < 0.05$). But the seawater vertical mixing also restricts phytoplankton growth in some perspectives. In the well-stratified area, phytoplankton is trapped in the surface layer to receive sufficient sunlight for photosynthesis, but they are mixed from the upper layer to the bottom by turbulence (Dorrell et al., 2022), resulting in inhibition of the effective photosynthesis process of phytoplankton.

(ii)

Oxygen depletion

The level of dissolved oxygen (DO) in seawater is an essential limiting factor for phytoplankton growth, which is deeply affected by OWFs operation (Baeye and Fettweis, 2015; Janßen et al., 2015; Floeter et al., 2017). Reef effect is caused by the alterations of pristine soft sediments to complex hard substrate habitats or inducing artificial structures, such as monopile foundations, cables, and score protections of OWFs, in the ocean ecosystem to act as shelters or habitats for suspension feeders (Krone et al., 2013; Nall et al., 2017).Under desirable conditions, those sessile organisms, dominated by blue mussels, would multiply biomasses that exceed surrounding mussel beds by order of magnitude (Janßen et al., 2015). Their metabolic activities, including respiration, excretion, and digestion, would consume oxygen resources and lead to a drop in DO in the surrounding ocean area (Chamberlain, 2001). The DO concentration in the mussel culture sea area could decrease to less than 3 mg/L (Weston et al., 2008). The sustainable growth of marine phytoplankton requires exceeding 6 mg/L in the DO level (Chen et al., 2003). Thus, Inadequate oxygen supply by the proliferation of mussels restricts the necessary respiration process of phytoplankton, resulting in the oceanic primary productivity reduction. Moreover, a five-year sampling study was conducted in the southwestern Baltic Sea and indicated that the local anoxia caused by the operation of OWFs would lead to the emission of hydrogen sulfide on the microscale level (Janßen et al., 2015), which was more detrimental on phytoplankton growth. Additionally, the shading effects of OWFs also impede phytoplankton from receiving adequate oxygen and sunlight for growth, especially for the area exactly under the wind turbine.

(iii)

Predation pressure

The foraging relationship between phytoplankton and marine primary consumers is another growth-limiting factor. The artificial structures of OWFs are desirable platforms for invertebrates and phytoplankton attachment (Farr et al., 2021). The dominant species on the spindrift splashing zone of piles usually are algae, including green algae, red algae, and diatom (Krone et al., 2013). But in most cases, mussels and other epifaunal species are the dominant residents on piles. Over 265 kg of Mytilus edulis was collected on each pile at an OWF in the German Bight (Joschko et al., 2008). The suspended phytoplankton in the water column serves as their indispensable food source (Mavraki et al., 2020b), decreasing in the abundance and biomass of phytoplankton. Slavik et al. found that over 40% increase in the overall abundance of *Mytilus edulis* altered the pelagic primary productivity via removing phytoplankton from the water column by filtration after the operation of OWFs in the southern North Sea (Slavik et al., 2018). Except for the decrease in the gross abundance of phytoplankton, the species composition might also be altered by the installment of OWFs. Zhang et al. (2020a) compared the phytoplankton species composition after the construction of OWFs in the Fuqing Xinghua bay, China, and found that the community composition of phytoplankton changed from 77 diatoms, 4 dinoflagellates, and 1 cyanobacteria to only 23 diatoms and 3 dinoflagellates living in that bay. Table 2 lists several case studies on the species composition alteration caused by the OWFs construction. Overall, under those multiple impacts of OWFs installation on phytoplankton, the primary production would fluctuate within ±10% at the OWFs clusters and extended region (Daewel et al., 2022).

Table 2. Changes on phytoplankton community composition by installment of OWFs.

Location	Pre-construction	Post-construction	F
Fuqing Xinghua bay, China (Measured data)	*Skeletonemacostatum; Chaetoceroscurvisetus; Paraliasulcata*	*Skeletonemacostatum*	(2 2
Donghai, China (Measured data)	*Skeletonemacostatum; Coscinodiscus jonesianus;*	*Skeletonemacostatum; Coscinodiscus jonesianus; Coscinodiscus oculusiridis*	(2 2

3.1.2. Marine vegetation

Besides phytoplankton, other macroalgae, such as kelp, are another category of primary producers in the food chain. Currently, inadequate studies have been performed to assess the impacts of OWFs installation on marine plants, but positive and negative impacts indeed exist.

(i)

Habitat invasion

Vegetations usually southerly grow on gentle slopes or sheltered sides of rock or bedrock with high rugosity. Drilling and pile-driving activities in the construction stage inevitably lead to the physical destruction of the benthic soft-sediment space, which is unfavorable for endemic seagrass growth (Kulkarni and Edwards, 2022). The wind turbines that shade southerly orientation have also been indicated to endanger small kelp plants in altering their available habitats (Schläppy et al., 2014).

(ii)

Water quality change

After OWFs are put into service, the alterations of seawater physicochemical properties, sediments resuspension, the attraction of primary consumers, and other interferences are speculated to affect the growth of marine vegetation. But a five-year monitoring of seagrass in the Öresund strait found that the quality of seagrass did not have obvious distinctions compared with the reference areas, which indicated the operation of OWFs may not have long-term impacts on seagrass growth (Hammar et al., 2016). Thus, the impacts of OWFs activities on marine vegetations should be systematically assessed in further studies.

(iii)

Conservation effect

Dredging activities are likely to be prohibited within the area in the vicinity of OWFs clusters to mitigate accidental damage to facilities. The associated spillover effect provides a long-term stable period for marine plant growth. Schläppy et al. found a naturally mature kelp population with a higher diversity of associated species on the Western coast of Norway after the construction of OWFs (Schläppy et al., 2014), indicating an ecological restoration.

3.2. Zooplankton - primary consumer

Zooplankton plays an essential role in the marine ecosystem since they are the intermediary in the food chain that links the lower and higher trophic levels (Ndah et al., 2022). The abundance and composition of marine zooplankton are prone to be affected by the construction of OWFs (Fig. 3). Tables 3 and 4 show the biomass and community composition changes of zooplankton after OWFs construction.

(i)

Temperature and oxygen alternations

Table 3. Comparison of zooplankton biomass before and after OWFs construction.

Location	Project stage	Biomass	P/B	C/B	EE
Rudong OWF,	Pre-construction	27.0618 (ton/(km^2*year))	106.0	–	0.49

China (Simulated data)	Post-construction	23.8560 (ton/(km^2*year))	150.0	–	0.49
Normandy, France (Simulated data)	Pre-construction	3.24 (g C/(m^2* year))	150.0	–	0.75
	Post-construction	3.24 (g C/(m^2* year))	150.0	–	0.99
Bay of Seine, English Channel (Simulated data)	Pre-construction	1.72 (g C/m^2)	–	–	0.88
	Post-construction	1.71 (g C/m^2)	–	–	0.99
Fuqing Xinghua Bay, China (Measured data)	Pre-construction	86. 3 (mg/m^3)	–	–	–
	Post-construction	814. 4 (mg/m^3)	–	–	–

Note: P/B: production/biomass; C/B; consumption/biomass; EE: ecotrophic efficiency; -: No available data.

Table 4. Changes on zooplankton community composition by installment of OWFs.

Location	Pre-construction	Post-construction	Ref
Fuqing Xinghua bay, China (Measured data)	*Paracalanus aculeatus; Paracalanusparvus; Calanus sinicus*	*Paracalanusparvus; Centropagestenuiremis; Cysticercosis longtail; Oithonasimilis; Copepod nauplius*	(Zha 202

The OWFs operation could produce anthropogenic mixing in seasonally stratified sea areas, leading to alterations in the hydrographic, hydro- and thermodynamics properties of seawater in the ambient area (Dorrell et al., 2022). Seawater temperature alteration is an essential factor to zooplankton. The temperature of the upper layer of seawater is usually higher than the sublayer water under a stable stratification due to the increased heat from solar radiation, especially in summer (Zisserson and Cook, 2017). The temperature differences in the North Sea fluctuated from 5 to 10°C between the different water column layers (Carpenter et al., 2016). The turbulent mixing would destroy the thermal stratification of seawater and cool the upper water, affecting the feeding and breeding behaviors of zooplankton with high sensitivity to ambient temperature (Christiansen et al., 2022). Beaugrand et al. (2014) found that the abundance of copepod species strongly correlated with the observed monthly sea surface temperature from 1958 to 2009 in the North Atlantic. Moreover, the oxygen depletion on the surface layer caused by upwelling and elevated temperatures changes the physiologic, behavioral, and reproductive activities of various zooplankton (Liu et al., 2009). Wang et al. (2018) investigated the zooplankton community in the Jiangsu coastal area and concluded that the operation of OWFs dramatically reduced the quantity of the microzooplankton (26.70% to 96.87% from autumn to spring) while significantly increasing the microzooplankton abundance (542.76%). Canonical correlation analysis, redundancy and multiple regression analysis indicated that water temperature and DO were primarily responsible for those variations (Wang et al., 2018).

(ii)

Sediment resuspension

Upwelling and downwelling turbulences near the monopiles would resuspend the original stable marine sediments (Dugdale et al., 2006; Broström, 2008). This phenomenon of water-sediment interface destruction might be more noticeable in the construction phase. The sediments resuspension might facilitate the proliferation of zooplankton since it enhances detrital organic particles diffused into the upper layer of the water column, which are reliable carbon sources for zooplankton (Shields et al., 2011). These additional nutrient sources promoted the zooplankton biomass from 11.96 to 14.85 ton/(km^2*year) at the Rudong OWFs, China (Wang et al., 2019) (Table 3). However, due to the resulting turbidity increase, zooplankton growth would be affected by hindering food intake or diluting the intestine's contents (Wang et al., 2018).

(iii)

Predation pressure

Zooplankton is preyed on by organisms at higher trophic levels controlling their abundance and biomass. The reef effect of OWFs creates the ideal condition for colonization by fouling organisms with high biomass. A previous study quantified that bivalves can form dense belts on the foundations of OWFs and occupied approximately 97% of the total epibenthic biomass (Maar et al., 2009). Marine zooplankton is one of the reliable food sources for these filter-feeding organisms (Östman et al., 2010). Hence, the reef effect, in turn, is able to reduce the micro- and meso-zooplankton biomass (Slavik et al., 2018). Additionally, the abundance and composition of phytoplankton play an essential role in controlling the distribution and abundance of zooplankton due to their predation relation.

3.3. Zoobenthos - secondary consumer

Marine zoobenthos refers to the organisms living on or within the sea floor, contributing heavily to marine biodiversity (Arlinghaus et al., 2021). They are generally located at the second or the third trophic level in the marine food chain and play indispensable roles in linking benthic organic matter and fishes (Sell and Kröncke, 2013). Thus, any changes on the species in the food chain would, in turn, affect their survival. Alternatively, unlike plankton that spends most of their lifetime suspended in the ocean, zoobenthos heavily relies on their benthic habitat, which means any disturbance on the seabed may also threaten their living (Fig. 4).

(i)

Habitat alteration

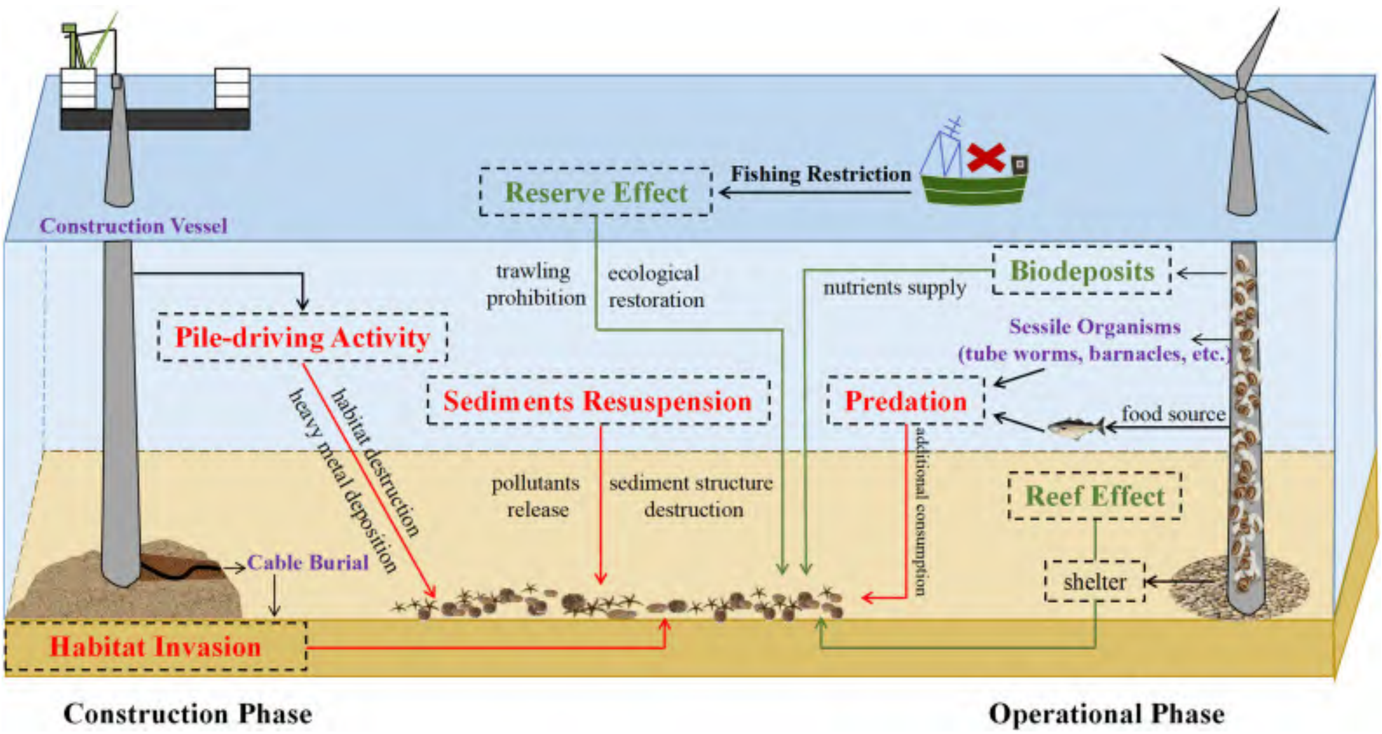

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Fig. 4. Ecological impacts on marine zoobenthos by application with OWFs.

The construction activities, including pile-driving, cable burial, and scour protection installation, directly destroy the living space of zoobenthos (Gill, 2005; Coates et al., 2014). This habitat invasion was potentially responsible for around 61.8% of zoobenthos biomass decrease in the construction phase (Defeo et al., 2009). But the impacts caused by construction activities are temporary for some zoobenthos, and they would recover quickly in the operation phase

(Powilleit and Kube, 1999). Besides direct destruction, the depositions of fine particles, like drill cuttings and fine-grained materials, into indigenous seabed potentially alter the overall sediment structure in the local region, thereby threatening the benthic communities (Wilson et al., 2010; Esteban et al., 2022). Meanwhile, the sediment plumes from construction activities and abnormal water mixing also release endogenous pollutants deposited in the sediments over the years, including various types of persistent organic pollutants and heavy metals, (Gopal et al., 2021; Rodriguez et al., 2021). Fang et al. investigated the impacts of Donghai Bridge OWFs on marine sediments and found that after the installment of OWFs, the mass fractions of all five heavy metals (Cu, Pb, Cd, Cr, Zn) in sediments experienced significant augments (17.1%, 36.6%, 9.5%, 7.3%, 64.3%, respectively) (Fang, 2015). Moreover, during the operation stage, the anti-corrosion systems of OWFs, copper-contained cables, and steel material in wind turbines are eroded to release heavy metals (Huang et al., 2017; Khim et al., 2018). It has been quantified that over 80 kg Al was released per monopile foundation each year from the anti-corrosion systems of OWFs in the German North Sea (Reese et al., 2020). These released hazardous substances might be toxic and even cause large-scale death to zoobenthos (Esteban et al., 2022). In contrast, A nutrient-rich benthic environment might be created by accumulating the biodeposits generated by sessile organisms

(Chamberlain, 2001; Attard et al., 2019). Previous studies have quantified that *Mytilus edulis* could produce 9.20 kg/(m^2*year) feces and 2.71 kg/(m^2*year) pseudofeces (Janßen et al., 2015). Coates et al. found that the organic matter content of sediments rose from 0.4% ± 0.01% to 2.5% ± 0.9% near the foundations in the North Sea and this change triggered a promotion in the microbenthic density from 1390 ± 129 to 18,583 ± 6713 individual/m^2 and 10 ± 2 to 30 ± 5 species per sample in species diversity (Coates et al., 2014).

(ii)

Reef effect and reserve effect

Although the benthic habitats are partially destroyed in the construction phase, establishing OWFs benefits zoobenthos by forming artificial reefs and refuges in the operation phase. The main structures of OWFs, such as foundations and score protections, provide the hard substrates that are scarce in the marine environment. After a period of time, some typical zoobenthos, mainly sessile species, crabs, and starfish, would colonize those artificial reefs (Öhman et al., 2006). A single foundation structure was predicted to create 2.5 times more habitats than it destroyed (Carpenter et al., 2016). Lu et al. quantified that, after the operation of OWFs, the benthic abundance experienced a 94.75% increase due to the addition of artificial structures into the offshore ecosystems in Pinghai Bay, China (Lu et al., 2019). Furthermore, the operation of OWFs might provide an unintentional reserve effect for zoobenthos since the entire inhibition of bottom trawling activities to meet navigational safety requirements and reduce the risk of damage to cable infrastructure (Hammar et al., 2016). When the trawl boards swipe over the seabed, they seem like plows to catch massive macro-benthos and exhaustively destroy benthic habitats (Thurstan et al., 2010). Thus, prohibiting trawling activities is estimated to provide over 30 years of ecological conservation for benthic communities (Hammar et al., 2016).

(iii)

Predation pressure

Zoobenthos locate at the middle trophic levels, which is critically important for the stability of the marine food chain. The colonizing organisms on OWFs structures have diverse food sources to support their higher trophic levels, especially vagile benthic megafauna like crabs (*Cancer pagurus*) (Krone et al., 2017). The reliable and sustainable food sources is vital to those massive propagation of new residents, sessile organisms, in the marine food chain. Moreover, several studies also have indicated that the turbine structures attract fishes and mammals to the surrounding area (Gill, 2005; Hammar et al., 2016). This augmentation of species at higher trophic levels inevitably increased the predation pressure of zoobenthos. Additionally, in Sections 3.1 and 3.2, the impacts on the phytoplankton and zooplankton have been illustrated in detail. The abundance of zoobenthos is strongly associated with the distribution and density of marine plankton since they are the most reliable food source for benthic organisms.

3.4. Marine fishes - tertiary consumer

Fishes are the most abundant residents in the ocean ecosystem that provide high economic value for humans. They are roughly divided into three categories: herbivorous, carnivorous, and omnivorous fishes, which also place them in the third and higher trophic levels in the marine food chain. The establishment of OWFs would affect their normal life trajectory, spawning, foraging, communication, and other activities (Fig. 5).

(i)

Habitat invasion and reef effect

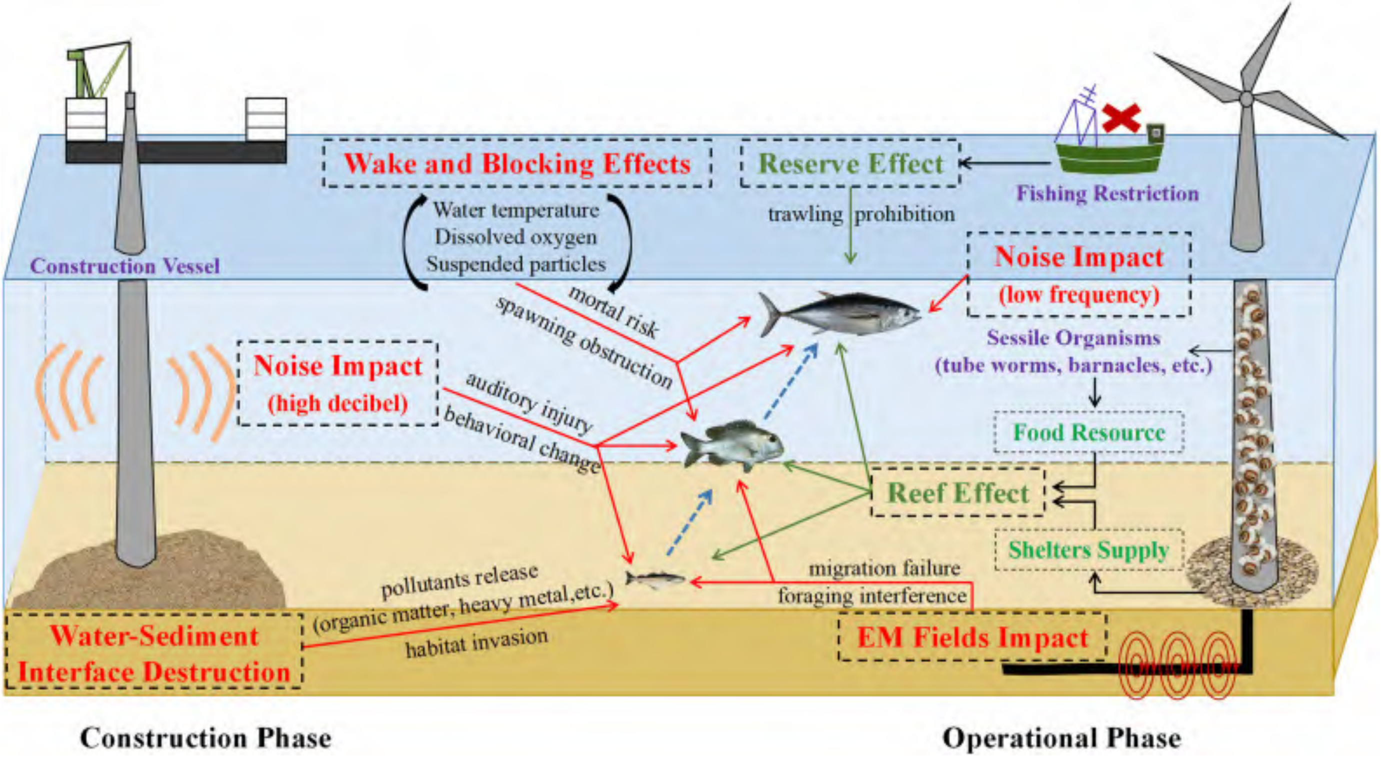

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Fig. 5. Ecological impacts on marine fishes by application with OWFs.

The direct destruction of pristine benthic areas, discussed in Section 3.2, severely breaks the habitats of benthic fishes (Wilson et al., 2010). Meanwhile, seabed habitats are also interfered with due to the hydrodynamic field modifications that enhance the scouring of soft sediments (Inger et al., 2009). This effect directly acts on benthic fishes and extends to pelagic fishes. However, compared with habitat destruction, the benefits of OWFs are the possible reef effect for marine fishes through shelter formation and food supply in the operation stage (Langhamer, 2012; Reubens et al., 2014). The hard structures supporting the turbines or protecting foundations change the primitive soft-sandy seabed and could attract hard substrate-associated fishes or their larvae to settle (Wilson et al., 2010; Hammar et al., 2016). Wang et al. (2019) found an apparent increase in the biomass of fishes from 0.0991 ton/(km^2*year) in 2007 to 0.5681 ton/(km^2*year) in 2015 in the Jiangsu coastal ecosystem. In addition, reef fishes are attracted by the attached organisms, including tube worms, barnacles, and sea squirts, through either direct consumption of those sessile species or indirectly receiving food by intake of deposited feces and dead bodies (Wilson and Elliott, 2009; Maar et al., 2009). This benefit tends to be more obvious for larval fishes due to their poor swimming ability (Gill, 2005). Reubens et al. (2013) investigated the behavior of Atlantic cod (*Gadus morhua*) at an OWF in the North Sea via acoustic telemetry. The results showed that around 75% of Atlantic cod were encountered on the windmill artificial reefs, while 97% were detected within 50 m of the turbine. Therefore, the impacts of shelter and food supply would form a hotspot for marine fishes in the ambient OWFs area. Furthermore, fishing activities are mostly prohibited within the OWFs area, which also benefits local fish communities.

(ii)

Noise and electromagnetic impacts

Marine fish communities are potentially interfered with by the noise wave from the turbines and electromagnetic (EM) fields from the cabling. Extreme noise with a high score is generated from pile-driving activities in the construction stage, and low-frequency noise is occurred by the rotor blades, mechanical and structural vibrations of turbine support, foundation, and nacelle in the operation stage (Kikuchi, 2010; Bergström et al., 2014). Different fish species display various levels of sensitivity to the generated acoustic waves. The operational noise detection radius of hearing generalist fish (dab and salmon) is 1 km, while this for hearing specialist fish (cod and herring) is up to 4.6 km (Thomsen et al., 2006). Sound signals are crucial for fish survival since they gather information by sounds to search for predators, prey, competitors, and mates and confirm the coordinates of migration routes or feeding grounds (Popper and Hastings, 2009). Thus, when the noise wave generated by OWFs interferes with or masks natural signals in the oceanic ecosystem, the indigenous fish communities' composition and diversity would be altered due to avoidance behaviors, navigation impairment, increased exposure to predators, prey access, or spawning partners reduction (Wilson et al., 2010). A previous study indicated that noise from pile-driving operations led to behavior changes in *Gadus morhua* and *Soleasolea*, and these impacts could even extend to over 10 km from the turbines (Su et al., 2020). The underwater noise level of pile-driving in Xinghua Bay OWF was an average of 197.7 ± 2 dB, 40–50 dB higher than the referenced area. This excessive noise significantly impacted indigenous yellow-croakers since the energy

distribution of piling noise overlaps with their auditory-sensitive frequency band (Niu et al., 2021).
In addition to acoustic waves, marine fishes are affected by EM fields generated by the buried electrical cables connecting the wind turbines and customers. The associated impacts include a decline in foraging ability and migration failure since some marine fishes use EM fields to navigate (Wilson et al., 2010). For instance, a constant magnetic field altered the swimming direction of trout (*Salmo trutta* L.) larvae and fry (Formicki et al., 2004). The ecological impacts of EM fields on marine fishes are species-dependent. Gill et al. (2005) listed marine fishes most likely to be affected by the EM fields generated by OWFs with 15 kinds of marine fishes, among which Angel shark (*Squatina squatina*) ranked first and Cod (*Gadus morhua*) ranked last.

(iii)

Wake effect

The turbulent wake by tidal currents movement change around OWFs foundation structures leads to changes in seawater quality, like temperature and turbidity, which affect the distribution and survival of marine fish (Paskyabi and Fer, 2012; van der Molen et al., 2014). The effect of water temperature change is species depended. Some species prefer lower water temperatures (<15°C), such as cod

(*Gadus morhua*) and herring (*Clupea harengus*). Others adapt higher water temperatures (>20°C), such as flounder (*Platichtysflesus*) and eel (*Anguilla*) (Olsson et al., 2012). In addition to the water stratification destruction resulting in temperature variation, the wind turbine running also elevates the temperature in the surrounding area. Bergström et al. (2013) investigated the impacting factors on the distribution patterns of benthic fish communities at the Lillgrund wind farm in Sweden and found that the temperature of the seawater close to the turbines (12.4 ± 1.6°C) in the operation stage was slightly higher than the referenced water before construction (9.6 ± 1.0°C), which partly contributed to the increase in the total fish biomass. Except for the temperature, the water turbidity also affects the marine fish, while the significance of this impact depends on the fish species and life stage (Gasparatos et al., 2017). The sediment resuspension leads to high mortality of fish eggs due to the promotion of the sinking to the seabed. It is lethal to marine fishes when the concentration of the suspended particles is on the scale of grams per liter (Hammar et al., 2014).

3.5. Marine mammals - top consumer

Marine mammals are enormous species located in the top trophic level of the marine food chain. The ecological implications on marine mammals caused by OWFs installations include habitat change, auditory injury, and behavioral reactions (Fig. 6).

(i)

Habitat change and physical impairment

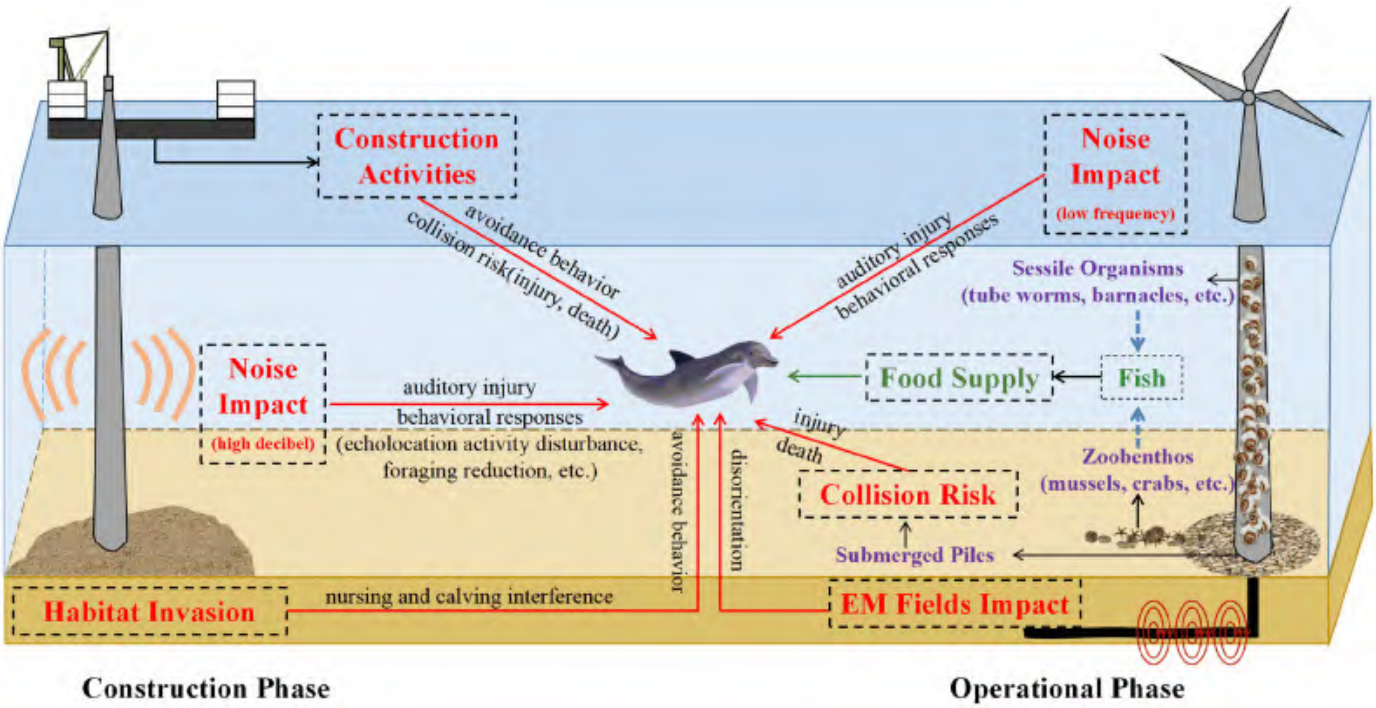

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Fig. 6. Ecological impacts on marine mammals by application with OWFs.

OWFs are usually constructed at submerged sandbanks, which are considered essential habitats for marine mammals, especially during nursing and calving periods (Koschinski et al., 2003). Except for breaking the habitat integrality, the mammals are driven from a certain distance from OWFs sites during construction by engineering activities and vessel movements (Benhemma-Le Gall et al., 2021). A noticeable decline in porpoise occurrence (16.7%)

was observed during turbine construction (Benhemma-Le Gall et al., 2021). Dähne et al. investigated the harbor porpoises' (*Phocoenaphocoena*) reactions to constructing of OWFs in the German North Sea and found porpoises gathering 25–50 km from the turbine to avoid pile-driving activities (Dähne et al., 2013). But other studies also demonstrated that the displacement of porpoises is likely transitory (Dähne et al., 2013; Schuster et al., 2015). Moreover, the habitat conditions of mammals are probably deteriorated by contamination. The seawater quality is seriously degraded by the leaks or spills of hydraulic fluid from operating devices and the usage of biocides on operating devices (Simmonds and Brown, 2010). But this unexpected incident could be avoided by more strict supervision.

Furthermore, the equipment or structures in OWFs might cause physical impairment to marine mammals through entanglement and collision (Lloret et al., 2022). For instance, cetaceans possibly collide with rotating turbine blades and get entangled in mooring or other cables, which results in wounding or death (Simmonds and Brown, 2010). Marine mammals could also be scared by the construction or maintenance of vessel activities in the operation stage (Esteban et al., 2022). The detected acoustic activity and the occurrence probability of porpoise were indicated to decrease by 24.5% as vessel intensity increased from 0 to 9.17 min/km^2 (Benhemma-Le Gall et al., 2021).

(ii)

Noise and electromagnetic interferences

The natural behaviors of marine mammals, such as foraging, echolocation, and spawning, are disturbed by vibration and noise, particularly for the species that are highly sensitive to acoustic, like seals (*Halichoerus grypus*, *Phocavitulina*) and cetaceans (Schuster et al., 2015). Carstensen et al. (2006) found that the interval of echolocation activity of harbor porpoises increased 4 to 41 hr during ramming and vibration activities. The acoustic activity of harbor porpoises in the Danish North Sea was also decreased sharply within one hour after piling at the wind farm (Brandt et al., 2011). As the responses to piling noise in the construction stage, gray seals changed in surfacing or diving behavior with less time in the bottom area for foraging (Aarts et al., 2018). In addition to behavioral responses, the temporary hearing impairment may also occur in marine mammals near construction sites (Dähne et al., 2014). Bailey et al. (2010) stated that auditory injury and behavior change occurred to bottlenose dolphins (*Tursiops truncatus*) within 0.1 km and 50 km of the piling site, respectively. The noise in the operation phase usually has weaker intensity and lower frequency than in the construction stage (Kikuchi, 2010). The cumulative impacts of auditory injury on the hearing system are potentially induced when mammals are successively exposed around the level above the behavioral reaction threshold in the operation phase (Dähne et al., 2014). However, some studies also proposed that underwater operational noise has negligible adverse impacts on marine mammals (Schuster et al., 2015). Thus, the long-term monitoring of operational noise impacts on mammals should be conducted to get further conclusions.

Besides noise interference, energized electrical cables potentially disorientate marine mammals navigating through the Earth's magnetic field (Gill, 2005). This confusion impact is species and intensity dependent. Cetaceans are more sensitive to magnetic fields, while the sensitivity of seals might be less noticeable (Gill et al., 2005; Hoffmann et al., 2000). Kirschvink et al. (1986) proposed that a variation within 50 nT on the magnetic field would affect the navigation behavior of cetaceans. The EM interference is much more extensive at floating wind farms, which require a larger size, longer and higher capacity subsea cables to interconnect the facility with the seafloor or the shore, increasing the range of EM fields in the water column (Farr et al., 2021). However, the actual impacts of EM field change around OWFs on marine mammals are still controversial, and it requires further studies on the perceptual ability of mammals on EM alteration.

(iii)

Food supply

The reef effect of OWFs could provide extra food resources for mammals (Schuster et al., 2015). Previous sections have illustrated that the structures of OWFs provide desirable habitats for sessile species, zoobenthos, fishes, etc., which are indispensable food resources for marine mammals. Two seal species (*Phocavitulina* and *Halichoerus grypus*) were observed using wind turbines and pipelines to forage (Russell et al., 2014). Raoux et al. (2017) figured out that marine mammals are beneficial from the aggregation of benthic biomass on piles and turbine scour protections. A study also found seals gathered around the wind turbine facilities of two different OWFs in Germany (*alpha ventus*) and England (*Sheringham Shoal*), and even slow their horizontal speed, indicating obvious foraging behavior (Russell et al., 2014). Furthermore, the reserve effect induced by fishing inhibition directly enhances the food supply to mammals by increasing the fish biomass and protecting mammals due to the associated spillover effect.

3.6. Interactions among trophic level species

The significant ecological impacts caused by OWFs were analyzed species-by-species in the sections mentioned above (Fig. 7). However, since the species at different ecological niches are not an independent unit, the population and abundance dynamics of any species would have extended impacts on other organisms and lead to unpredictable consequence to the whole marine food chain.

(i)

Trophic cascade effects strengthen

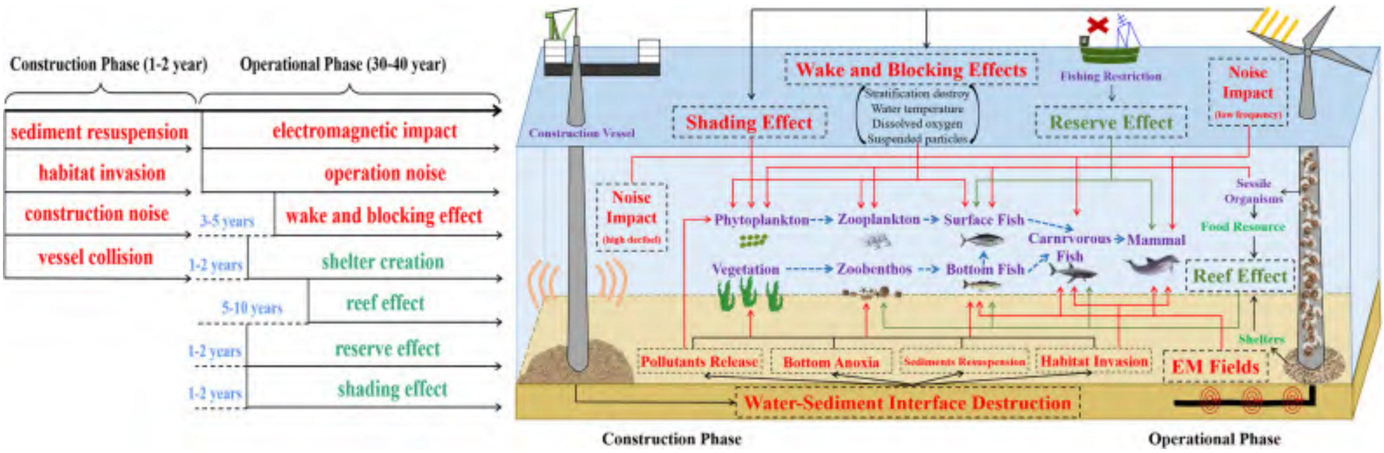

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Fig. 7. Ecological impacts on marine species at different trophic levels by application with OWFs.

Trophic cascade refers to the predator-prey effects which affect the abundance, biomass, or distribution across more than one species in a food chain (Pace et al., 1999). The reef effect triggers the associated impacts on the whole food chain by trophic cascades alternation. The artificial structures of OWFs could provide new colonization supports and scarce habitats for filter-feeding invertebrates and bivalves, like blue mussels, amphipods, and anemones, increasing the total biomass of indigenous ecosystem over 40% (Coolen et al., 2020). Most of these sessile organisms are trophic generalists at second and third trophic levels, gaining different resources in various depths (Baulaz et al., 2023). Thus, after the installation of OWFs, the marine food chain is usually controlled by those filter-feeders at mid-trophic levels, rather than the primary producers or top predators (Raoux et al., 2017). The filter-feeders display a top-down control on low trophic level species (phytoplankton and zooplankton), and a bottom-up support on high trophic level organisms (fishes, and mammals). Specifically, the predation relations between plankton and filter-feeders decrease the marine annual primary production, not only at the OWFs sites but also distributed over a wider region (Daewel et al., 2022). It was estimated that 1.3% of the net primary producer standing stock is consumed by *M. edulis* and *J. herdmani* (Mavraki et al., 2020b). In addition, from the perspective of biodiversity support, the apex predators such as pelagic fishes and mammals are attracted to and benefit from the aggregation of filter-feeders on monopiles and scour protections of OWFs (Raoux et al., 2017). Due to the biomass increase of filter-feeders, the percentage of production consumed by predators of the whole marine food chain would promote 5%, indicating the increase in predation behavior by the organisms gathered by the reef effect (Raoux et al., 2017). As a result, after the construction of OWFs, the explosive growth of filter-feeders due to the reef effect will evolve the marine food chain into a more complex ecosystem through trophic cascades effects (Baulaz et al., 2023; Glarou et al., 2020), marked by an increase in the total biomass of ecosystem, massive proliferation of filter-feeders, the aggregation of predators with third and higher trophic levels.

(ii)
***Resource partitioning* change**

Resource partitioning is the capacity of species to allocate resources to avoid trophic competition, which is likely to affect species interactions in the marine food chain (Wu et al., 2018). After the construction of OWFs, resource partitioning might be an indispensable mechanism supporting the co-existence of large densities of an abundant variety of species (Mavraki et al., 2020a). The interactions among marine species in the food chain also evolve into a new order with less trophic competition, which are embodied in the various complexity of food chain along the depth gradient. The complexity of the food chain in the zones of the soft substrate and scour protection layer was usually higher than in deeper intertidal and *Mytilus* zones due to a different allocations of organic matter resources (Mavraki et al., 2020a).
Moreover, the resource transfers in the marine food chain also exhibit an alternation. Additional resources are distributed to the seabed through the deposition of organic material from high trophic level organisms like fish and crustaceans in the vicinity of the turbines, leading to the increase of the abundance of bottom trophic feeding

organisms and associated predators (Maar et al., 2009; Raoux et al., 2017). These abnormal organic materials from the wind turbines directly to the bottom communities are responsible for a ‘shortcut within the food chain’ since this resource supply directly links the high and low trophic species (Raoux et al., 2017). The primary producers also benefit from resource partitioning after the construction of OWFs. The growth rates of phytoplankton are enhanced through either direct extra food supply from blue mussels or cleaner water column for living by increased excretion of ammonium from filter-feeders to reduce the turbidity (Norling and Kautsky, 2008). Overall, the alternations on resource partitioning make the marine food chain evolve into a more sustainable, harmonious, and complex state with less trophic competition.

4. Ecological risk management and assessment of OWFs

Although numerous data on ecological impacts at the species or community scales have been investigated in previous studies, they mainly focused on evaluating the ecological impacts of OWFs on the individual type of larger species (birds, fishes, mammals, etc.). Field-measured data or modeling simulative results were usually applied to assess two points in time, “before” and “after,” and to compare the changes in biomass, abundance, and community composition before and after OWF construction. However, the ecological impacts on individual species or the whole ecosystem are cumulative due to several decades' operation time of OWFs. Recently, OWFs deployment is rapidly expanding worldwide since the urgent demand for renewable energy. Concerns about the long-term environmental impacts generated by these facilities on the marine ecosystem are rising by the public. The environmental issues generated by OWFs should be considered during the design and development phases. In order to mitigate the negative impacts and reveal the ecological impacts of the whole life of OWFs, the mitigation strategies of deployment and research suggestions of environmental impacts for OWFs development are discussed in the following sections.

4.1. Mitigation of the ecological impacts of OWFs

The scientific and rational deployment is the primary item to consider before building OWFs because the increased artificial structures at sea will affect almost every marine species (Gall et al., 2021).

The spatial site selection of OWFs is extremely vital for mitigating environmental impacts. The OWFs location should be kept away from critical and sensitive sea areas such as the habitat and breeding place of marine species, migration routes of birds, shipping lanes, natural scenic spots, and military sea areas. The “safe distance” and suitable location selection for OWFs installation could be proposed through the monitoring data, effective evaluation methods of ecological impacts on the marine ecosystem, and scientific simulation modeling (Liechti et al., 2013). Clarke indicated that OWFs should be installed at least 300 m from any nature conservation site (Clarke, 1991). In addition, the deep-sea area may be another suitable site for further expansion and development of OWFs, which may reduce the impacts on marine species and human life. Detailed surveys and evaluations for wind energy, bottom substrate, and species community distribution of the deep sea must be carried out before deploying OWFs. Meanwhile, the directions of ventilator equipment and power transmission line should be deployed beforehand to avoid habitat damage.

Furthermore, appropriate designs of blades and cables are crucial to reduce the emissions of noise and magnetic field from OWFs in the ocean environment. Noise and EM interference might induce some physiological impacts of auditory injury, foraging and courting, echolocation, and spawning on fishes and mammals. All the upwind turbines application (Frey RC, 2008), the insulations inside the turbine towers (Binopoulos, 2012) and the unique gearbox with semi-soft cores and hard surfaces (Association, 2012) can effectively reduce the low-frequency noise and mitigate the mechanical noise during the operation phase. Even though EM interference of OWFs was argued to be very limited (Binopoulos, 2012), this may lead to the degeneration of some physiological functions of top consumers at a long-term operation. Various measures such as improved and synthetic materials of blades and suitable site locations far away from gathering places of large marine animals can be used to minimize the problems.

Overall, based on the modeling simulation, novel mapping techniques, field inspections, and monitoring, the sea area where the minimum impacts on the ecological environment and human life can be selected as the suitable site for OWFs installment. The negative impacts of OWFs on biodiversity, marine industries, livelihoods, and people, can be alleviated with careful planning, which also considers the profitability of OWFs.

4.2. Life-cycle-assessment of the ecological impacts of OWFs

OWFs positively and negatively impact marine species in the exploitation, construction, operational, and decommissioning phases. The adverse effects generally occur during construction, while lower impacts might be expected in the operational stage due to long-term steady operation. Previous studies have also shown the beneficial and detrimental impacts on the specific species (e.g., sea birds, marine fishes, mammals) after OWFs construction. However, the evidence of impacts on the marine ecosystem in the whole life of OWFs is inadequate. Notably, research on environmental impacts during decommissioning phase is almost blank (Hall and Knapp, 2020). Hence, life-cycle-assessment is crucial to obtain systematic and comprehensive ecological impacts of the whole life of OWFs on the marine ecosystem. Moreover, field experiments and long-term monitoring are the primary sources of basic data for the research of the whole-life assessment of OWFs. Notably, there have not been any field experiments and long-term monitoring works on the OWFs sea area until now due to some limited factors such as operative technique, man-powered or financial resources. Based on the mentioned factors, some measures may help mitigate the restrictive conditions and promote the life-cycle-assessment research of OWFs. Firstly, the whole life of OWFs can be composed of the different periods (exploitation, construction, operation, and decommissioning phases) of OWFs located in the same sea area, which can break through the long-periodic life restriction of OWFs. Therefore, the ecological impacts of different phases of OWFs on the key species of the marine food web can be investigated and studied simultaneously, and the extended impacts of OWFs on ecosystem functioning can also be further researched synchronously. Secondly, together with field experiment monitoring data, the conduction of performance simulation methods of matter and energy transmission in OWFs micro-environment could reveal the scope and depth of environmental impacts during the whole life of OWFs. Thirdly, the key ecological service functions are also necessary to prove the environmental benefits of OWFs. The life-cycle-assessment and the qualitative modeling approach can be used to calculate and assess the ecological service values (e.g., carbon fixation, economic benefit, and environmental impacts) of the whole life of OWFs.

4.3. Assessment of carbon emission and deposition of OWFs

The aims of OWFs construction are to reduce carbon emissions and mitigate climate change. However, their operational activities and resulting impacts on the marine ecosystem would induce carbon emissions. A previous study concluded that most greenhouse gasses are released during the manufacturing process of supporting structures made of steel and depend heavily on the locations of OWFs (Reimers et al., 2014). Thus, it is essential to access the carbon emission and deposition by OWFs deployment in the marine ecosystem. In addition, from the perspective of the carbon pool of the marine food web, micro-organisms, such as phytoplankton and zoobenthos, play critical roles in the carbon cycle of the marine ecosystem. The ways to link the impacts of OWFs on organisms with carbon emission are essential for OWFs development.

Phytoplankton is not only the primary producer of the marine ecosystem but also the carbon-pump of the ocean, which significantly regulate global carbon circulation through photosynthesis. It is well known that the photosynthetic carbon fixation capacity of phytoplankton mainly depends on their species and biomass (Wang, 2011). Obviously, the biomass and community composition of marine phytoplankton would be affected due to the alteration of water physicochemical properties and predation relationship caused by OWFs construction, which can lead to changes in the total carbon fixation capacity of the regional-scale of OWFs ecosystem.

Zoobenthos are key coordinator of carbon fixation and mineralization at the bottom of the ocean. In this review, as one of the zoobenthos, the biomass of mussels exhibited a significant increase due to the reef effect of OWFs. The growth of mussels is a process of biological mineralization through the assimilation and translation of bicarbonate ions and particulate organic carbon into calcium carbonate bodies. It has been calculated that the carbon precipitation of mussels in fresh and sea water can reduce 0.0125% increased CO_2 in the atmosphere (Chen, 2010). Besides mussels, benthic bacteria is the maximum heterotrophic productivity (Kemp, 1988). The heterotrophic bacteria, flagellidia, and ciliates have amalgamated to form a

"Microbial loop" (Azam et al., 1983), which can deliver a large amount of matter and energy to the whole ecosystem. Specifically, bacteria transfer organic debris to dissolved organic carbon (DOC) and further mineralize to available nutrients. Meanwhile, bacteria assimilate DOC to synthesize cellular materials and enter the higher trophic level by flagellidia predation. The bottom micro-environment conditions, including basal surface, water temperature, DO, and carbon source (mainly phytoplankton and sediment), might determine communities' structure and metabolic function of benthic bacteria. However, the mentioned factors can be changed by OWFs construction, operation, and decommissioning. Therefore, it is valuable to investigate whether these changes are significant enough to affect the carbon circulation of the marine ecosystem and assess the carbon emission and deposition by OWFs deployment.

5. Conclusions and prospective

This review provides a holistic analysis of ecological impacts on the marine species from different trophic levels of the marine food chain and their interactions caused by OWFs construction and operation. In order to tackle the possible ecological risks that come from the rapid expansion of OWFs worldwide, further studies of ecological risk management, life-cycle-assessment of ecological impacts, and carbon emission and deposition associated with OWFs have been suggested in this article.

E**cological impacts of OWFs on different trophic species. (i) Phytoplankton.** The wake effect induced water hydrodynamics and quality alternations and predation pressure from suspension feeders have positive or negative impacts on phytoplankton, leading to *a* ± 10% fluctuation of marine primary production. **(ii)** M**arine vegetation.** Although their biotopes are destructed by construction activities, the spillover effects of fishing prohibition would provide a long ecological restoration period for vegetation in the operation phase. **(iii) Zooplankton.** The abundance and biomass of zooplankton are directly affected by the phytoplankton community due to predator relations. Moreover, they are also adversely impaired by turbidity rise, oxygen depletion, and additional consumption by suspension feeders. **(iv) Zoobenthos.** Although zoobenthos is negatively impacted by benthic habitat destruction with a 60% reduction of biomass in the construction phase, they get an ecological restoration over 30 years through the reef effect by the formation artificial shelters and reserve effect of trawling prohibition in the operation phase. **(v) Marine fishes**. Although marine fishes are adversely affected by the noise wave and EM field disturbances, they benefit from the reef effects, embodied in spawning shelter formation and food supply, causing an aggregation of fishes around OWFs clusters. (vi) Marine mammals are at the top trophic level of the marine food chain with solid resistance to external interference. The reef effect supplies additional food resources for marine mammals, but noise waves and EM field disturbances also threaten them for a long time. **The interactions among trophic level species.** The filter-feeders initial a top-down reduction of plankton and down-top aggregation of predators through trophic cascades effects strengthen; The marine ecosystem evolves into a more sustainable and complex state with less trophic competition via resource partitioning change.

Further research suggestions. Although no significant changes in marine species and ecosystems have been found before and after OWFs construction and operation, the ecological implications of the whole life of OWFs should be further studied, especially with the rapid expansion of OWFs worldwide. Scientific deployment and suitable site selection are the first principles for building OWFs. Life-cycle-assessment of ecological impacts on species and ecosystem of OWFs should be carried out with field monitoring data and quantitative model simulation. Additionally, the carbon emission and deposition within the regional ecosystem of OWFs location should be considered in future studies.

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.

Acknowledgements

This work was supported by the National Key R&D Program of China (No. 2022YFE0209500), the Industry-Academy cooperation project (No. E2021000435), the National Natural Science Foundation of China (No. 41877310), the Network Information Security and Information Special Application Demonstration Project (Cultivation Project) of Chinese Academy of Sciences (No. CAS-WX2023PY-0103), and the Innovative practice training program for college students of Chinese Academy of Sciences (No. 117900M002). The authors thank Prof. Kai Xue of UCAS for helpful discussions on this work.
View Abstract

Toxic Blade Time Bomb

by Mark Mallettin Home, Environmental, Human Healthon November 28, 2024

We have documented the threats of industrial wind turbines to both soil and water in their pre and post-construction phases, not to mention birds, bats, insects, and humans. But not enough has been said about the serious environmental threat of "blade shedding." This is erosion that occurs primarily on the edge of turbine blades as they are exposed to the elements. And it is far from benign:

> Microplastic shedding from turbine blades, known as Leading Edge Erosion, is a great concern to manufacturers who are forced to repair the damage that occurs after only a couple of years. The particles eroded from blades include epoxy which is 40% Bisphenol-A (BPA), a frequently banned endocrine disruptor and neurotoxin. Academic research has shown the potential for 137 pounds of epoxy microparticles to be shed per turbine per year.
>
> *Mark Twichell, Citizens Against Wind Turbines In Lake Erie, March 21, 2023, The Buffalo News*normal

Bisphenol-A or BPA is among the most toxic of man-made substances. Manufacturers of everything from juice jugs to appliances are making a point of claiming that their products are “BPA free.” Not so with industrial wind turbines, whose blades contain BPA in their resin coating.[1])

Mitchell is referring to a paper out of Norway, “Leading Edge erosion and pollution from wind turbine blades” (Solberg et. al.) that examined the data of a U.K. study on rain erosion by Pugh et. al..[2] The Norweigan authors assert that, “With large emissions of toxic compounds from the wind turbine industry, this industry will be exposed. Wind turbines can have major ecological, health and economic consequences. We do not know any wind turbine facilities having applied for or received emission permits.” That’s likely the case nearly everywhere in the world as this issue of BPA shedding has hardly been addressed by local regulatory bodies, if at all.

While the Norweigan analysis calculates 62 kg (137 lbs) of material loss from each turbine annually, perhaps not unsurprisingly, the wind industry there comes in at 41,000% less in their estimates: 150 grams per blade. In Solberg’s paper, however, they calculated that 20 turbines (130m rotor diameter) could release up to 24.8 tons of material over the course of their lifetime (approximately 20 years).

> The wind power industry has chosen to neglect and under-communicate this in much the same way as the tobacco industry dealt with health effects.

> *Pollution from wind turbine blades, Solberg et. al., pg. 6*normal

That said, it doesn't take much BPA to have a highly toxic impact. Turbines spin at high speeds up to 300km/h at the tip of the blade.[3] This, then, is where the greatest shedding of material occurs, releasing BPA into the air, soil, and possible nearby waterways. Given that turbines are placed in generally high wind locations, and are generating strong wind themselves to the point that they can create drought conditions,[4] these toxic microparticles can potentially travel long distances. And it only takes a *fraction* of a gram for this substance to poison a single litre of water:

> 1 kg of BPA is enough to pollute 10 billion litres of water. That's 10,000,000,000 litres. Since 2017, the WHO has advised that drinking water should have a maximum of 0.1 micrograms of BPA per litre. That is the same as 0.0000001 grams per litre of water.
>
> *Asbjørn Solberg, Bård-Einar Rimereit and Jan Erik Weinbach, 08/07/2021, "Leading Edge erosion and pollution from wind turbine blades," p. 15*normal

Material loss on blades is attributed primarily to dust, salt particles, hail, and rain (known as the "Water Hammer pressure effect"). When you add the additional impacts of ice or hail, the loss on blades is magnitudes higher and "can be detrimental to its structural integrity," said Kugh et. al in a study on turbine rainfall impacts. The implications are significant for wind turbines in Canada where hail storms are a normal feature of Canadian summers. In a study examining ballistic ice impacts on turbine blades, it was shown that "the impact would delaminate and crack the composite material," ultimately hastening the loss of blade resin.[5]

Moreover, in Solberg's study, they note that the loss of material increases "exponentially" the larger the turbine blades. This is alarming, given that off-shore-sized turbines are now being built on land *next to people's homes and farms*. For instance, the turbines proposed among the acreages and farms of the Northern Valley near Elk Point in Alberta, Canada are 679 ft (207m) tall, from base to blade tip. As the wind industry graph below shows, this is clearly entering new territory (ie. experimentation on humans by the wind industry). And yet, the impacts on humans, from blade shedding to infrasound, are barely acknowledged much less properly studied.

Source: Energy.gov

The Trojan Horse Effect

The European Union is beginning to recognize the threat of BPA entering our ecosystems and eventually our bodies, as noted by the Norwegian Environmental Protection Agency (NEPA).

> ...the EU is preparing new, stricter regulation... What is particularly disturbing is the fact that a lot of bisphenols and other toxins are released from the particles *when they enter the intestinal system*, which often has an acidic environment with low PH. They are also released with increasing temperatures and go up in the food chains where they are concentrated more and more. In the end, a lot of the toxins we release will end up on our

> own dinner table and drinking water. This is the "Trojan horse effect".
>
> *Bergensia, "Bisphenol A in wind turbines damages human fertility", The Norwegian Environmental Protection Agency (NEPA), March 22, 2021*normal

NEPA adds that "Substances such as Bisphenol A and similar substances do very great damage to the reproduction of most organisms and in us humans." They highlight a "very disturbing study" that shows that Bisphenol-A causes genetic damage for several generations in rainbow trout. "We also risk irreparable damage to the entire environment both on land and at sea if we do not limit or stop the use of such substances, and especially the deployment of new wind power plants in increasingly demanding environments or at sea."

In an article to *Iowa Climate Science Education*, Dr. Eric Blondeel warns, "It should be known that exposure to endocrine-disrupting chemicals has been linked to about 80 diseases. These include testicular cancer, obesity and reproductive disorders."

"The resulting annual BPA release can potentially contaminate 17 million gallons of drinking water per turbine while threatening aquatic and terrestrial life", says Mitchell. Given that turbines are increasingly being erected among rural communities, this should be considered an environmental disaster in the making.

Add to the above what happens when a wind turbine collapses, implodes, or burns up — events which are occurring with greater frequency around the globe. But little is said about the aftermath of toxicity that is left behind. Not to mention that, when turbine blades reach their end of life, they are usually buried in landfills where BPA can leech into groundwater.

BPA in blades is just one more of a very, very long list of reasons why industrial wind farms are not saving the planet but destroying it.

1. "Leading Edge erosion and pollution from wind turbine blades" (Solberg et. al.[↩]
2. "Rain Erosion Maps for Wind Turbines Based on Geographical Locations: A Case Study in Ireland and Britain", January 22, 2021[↩]
3. Leading Edge erosion and pollution from wind turbine blades" (Solberg et. al.) [↩]
4. cf. https://www.windconcerns.com/winds-assault-on-our-water/[↩]
5. Keegan MH, Nash D, Stack M. *Wind Turbine Blade Leading Edge Erosion: An investigation of rain droplet and hailstone impact induced damage mechanisms* (Doctoral dissertation, University of Strathclyde) [↩]

DEPARTMENT OF WATER RESOURCES
P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

California Fish and Game Commission
P.O. Box 944209
Sacramento, CA 94244-2090
fgc@fgc.ca.gov

October 31, 2024

Dear President Murray, Vice President Zavaleta, and Commissioners Hostler-Carmesin, Sklar, and Anderson,

The Department of Water Resources (Department) planned, constructed, and operates the State Water Project (SWP), which supplies water to more than 27 million people in California, irrigates approximately 750,000 acres of farmland, and provides multiple other benefits including flood control, power generation, recreation, and fish and wildlife habitat. Unfounded information about the Department's compliance with its obligations under the California Endangered Species Act (CESA) was aired at the Commission's meetings on June 19 and 20, 2024. I write to clarify and correct the record about the relationship between the SWP and white sturgeon abundance.

On June 27, 2024, following the Commission's consideration and determination at its June 19-20 meeting, white sturgeon became a candidate species subject to CESA protections under section 2068 of the Fish and Game Code. Numerous interested parties commented at the meeting about the petition to list white sturgeon and the Commission's consideration to grant candidacy status. Department representatives attended the Commission meeting and were concerned that some of the presentations and comments shared caused confusion about the SWP's true extent of white sturgeon take. Contrary to the implications in statements made by some speakers, SWP Delta operations take few white sturgeon, and magnitudes lower than other activities such as commercial and recreational fishing. As the attached table shows, white sturgeon salvage[1] totals at the SWP's pumping facilities have been in the tens of fish or, in many cases, zero fish per year since Water Year 2012. These salvage totals do not represent "loss" because most salvaged white sturgeon are successfully translocated downstream.

Even though the SWP's take level is low, the Department is working with the California Department of Fish and Wildlife (CDFW), agency partners, and interested parties to understand factors that influence the timing and magnitude of white sturgeon take at the SWP Delta pumping facility. The Department has proposed and will draft, in collaboration with a newly established White Sturgeon Technical Team, a White Sturgeon Science Plan to identify science needed to improve our understanding of white sturgeon ecology and impacts of SWP operations on the species. The Department will provide an annual commitment of funding to implement monitoring and science set forth in the Plan, consistent with its proportional share of impacts. The Department is discussing habitat restoration needs and will fund at least $150,000 toward the evaluation of potential projects benefiting white sturgeon in the Sacramento and San Joaquin rivers. The Department is undertaking mitigation projects under existing obligations, including the Yolo Bypass Salmonid Habitat and Fish Passage Project and removal of the Sunset Pumps on the Feather River, which

1 "Salvage" represents the number of individuals collecting at the Skinner Fish Facility screens. Fish are collected, and then transported and released downstream of the Delta. Fish Salvage Monitoring (wildlife.ca.gov/Conservation/Delta/Salvage-Monitoring)

will improve conditions and passage for white sturgeon. In addition, the Department funds 10 warden positions at CDFW to deter poaching of species including white sturgeon.

The Department already has secured white sturgeon CESA take coverage for its current SWP operations through an amendment to its existing Incidental Take Permit (ITP) and, in November 2023, submitted an application to CDFW for a new ITP associated with updates to long-term operations of the SWP which, when issued, will continue to provide coverage for white sturgeon.

I hope this letter clears up any misperception about the SWP's take of white sturgeon in the Delta. The Department will gladly provide additional material upon request. In addition, for further information, the Department refers the Commission members to the June 6, 2024, letter from the State Water Project Contractors, Inc. and San Luis & Delta-Mendota Water Authority regarding potential white sturgeon listing.

Thank you for the work you do on behalf of all Californians and thank you for allowing me to clarify this issue.

Sincerely,

Karla A. Nemeth

Karla Nemeth, Director
California Department of Water Resources

Attachment

Cc: Charlton Bonham, Director
California Department of Fish and Wildlife

Salvage of White Sturgeon (length in Millimeters in Parentheses) at the State Water Project Skinner Fish Facility, October 1, 2012-May 20, 2024

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2012	0	0	0	0	0	0	0	0	12 (358)	0	0	0
2013	0	0	0	6 (378)	0	0	0	6 (309–352)	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	2 (370)	3 (360)	4 (410)	0	0	4 (80)	2 (144)	12*	8 (237)	0
2018	0	1 (250)	18 (225–290)	0	0	0	4 (349)	0	0	0	0	0
2019	0	0	0	8 (489–540)	0	4 (537)	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0
2023	0	0	0	0	0	0	0	0	0	0	0	2 (311)
2024	0	4*	20 (296–401)	11 (291)	34 (227–376)	0	0	0	–	–	–	–

Source: Aasen 2024.
Note: Abundance numbers are extrapolated from salvage sampling, so not all fish were measured for length.
* Length measurements not available.

Outlook

Fwd: WCB meeting, November 21, 2024. Agenda item 18: Lake Earl Wildlife Area, Del Norte County..for Phoebe, when convenient, thank you

From Phoebe Lenhart <[redacted]>
Date Thu 11/07/2024 11:24 AM
To FGC <FGC@fgc.ca.gov>

Sent from my iPhone

Begin forwarded message:

> **From:** Phoebe Lenhart <[redacted]>
> **Date:** November 6, 2024 at 1:04:01 PM GMT-8
> **To:** DN Office Supply <dnofficecc1@aol.com>
> **Subject: Fwd: WCB meeting, November 21, 2024. Agenda item 18: Lake Earl Wildlife Area, Del Norte County..for Phoebe, when convenient, thank you**
>
> Sent from my iPad
>
> Begin forwarded message:
>
> > **From:** Phoebe Lenhart <[redacted]>
> > **Date:** November 6, 2024 at 1:03:12 PM PST
> > **To:** mary.ahern[redacted]
> > **Subject: WCB meeting, November 21, 2024. Agenda item 18: Lake Earl Wildlife Area, Del Norte County**
> >
> > Deader WCB,
> >
> > This email is sent to address a concern that is under consideration at your November 21, 2024 meeting. It is agenda item 18: Lake Earl Wildlife Area, Del Norte County.

First, I must bring to your attention that the WCB posted a “Preliminary Agenda Items”
”agenda” that lists a deadline “…by close of business on Thursday, November 7, 2024”. I called the WCB, because NO email address was provided to the public to where comments could be sent. I was told by a staff person to “ignore” the “Preliminary” agenda and that the final agenda will be posted on November 7 or 8. This was confusing to me since a deadline of November 7 was listed. The staff person at WCB told me to “ignore” the deadline date of November 7. If I want my comment to be considered, WCB provided no reassurance, under this protocol of posting the final agenda later in the week, that public’s comments would be collected.??

Thus, I request that the WCB provide for the public the email address for comments in the “Preliminary Agenda Items” post. As well as, to please be more prompt in publicizing the final agenda so that the public has ample time to respond. WCB, please reply to my request. I wish to know that WCB will consider my request to improve.

Agenda item, 18: Lake Earl Wildlife Area, Del Norte County.

I am a resident of Del Norte County and would like the WCB to also consider and include in this acquisition (of approximately 3 acres by the DFW) “…and numerous bird species INCLUDING THE ALEUTIAN GEESE ,”. I do not know if the WCB is aware that flocks of Aleutian geese used to migrate to Del Norte County (many years ago)? They migrated to Del Norte County until the behavior of a farmer ruthlessly razed the Aleutian geese to the point that it impacted their migration flight out of DNC. Thus, I am specifying the bird species “Aleutian geese” so that the WCB is aware of the razing this species suffered in Del Norte County and will be alert to protect the Aleutian geese from a future harassment.

Your consideration will be appreciated. Please respond to confirm that the WCB received my email. Thank you in advance.

Take care,
Phoebe Lenhart
[redacted]
Crescent City, CA

Sent from my iPad

Outlook

Western Joshua Tree

From John Lusk <[redacted]>
Date Wed 11/27/2024 09:08 PM
To FGC <FGC@fgc.ca.gov>

There are many trees that have fallen over in people's yards or property due to various reasons. The heavy rains caused many trees to collapse due to their shallow roots. It's not fair that those affected have to pay thousands of dollars just to remove what is already down.
Respectfully,
John Lusk
[redacted]
Sent from my iPhone

Outlook

letter for the meeting coming up on 12/11

From Donna Kalez <[redacted]>
Date Fri 11/29/2024 12:41 PM
To FGC <FGC@fgc.ca.gov>

Thank you

Donna Kalez, COO
Dana Wharf Sportfishing & Whale Watching
34675 Golden Lantern
Dana Point, Ca. 92629
949.496.5794 ext 116
www.danawharf.com
www.linktr.ee/danawharf
Dana Point : The Dolphin & Whale Watching Capital of the World ®
https://youtu.be/Tk0Uu9Vb-Jg?si=GLH_bJtzt2ty-dh_
Keep in touch: **Twitter**, **Facebook** , **Instagram** , **You Tube**

Chair: Festival of Whales Foundation

Oceanside Adventures
256 Harbor Dr. South
Oceanside, Ca 92054
www.oceansidewhalewatching.com

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EST. 1971

11/25/24

California Fish and Game Commission
1416 Ninth Street, Suite 1320
Sacramento, CA 95814

Dear Commissioners,

My name is Donna Kalez from Dana Wharf Sportfishing and Whale Watching. Also a Board Member of Fish for Life, a fishing charity ,our mission is Bringing Dignity, Inclusion and New Possibilities to Special Needs Children!" and we just finished our 15th season , we had trips in Dana Point , Santa Barbara and New Jersey this year . Total of 7 trips this year .
During all the 15 years we have had support from DFG , this year in particular we had DFG personnel on all our trips - we would like to thank Marine Region manager Dr. Craig Schuman for his support for this program, in fact he volunteered himself several times this year
We would also like to give a special thanks to Amanda Van Diggelen who did an amazing job this year coordinating Fish & Wildlife personnel to be on every trip.

Here is the list of Fish & Wildlife participants:
Craig Shuman
Amanda Van Diggelen
John Ugoretz
Liz Hellmers
Claudia Makeyev
Ben Barnes
Steve Wertz
Dianna Porzio

In addition, Amanda scheduled Game Wardens to come aboard 3 Dana Point trips.

Having Game Wardens like Warden Matthies participate adds significant educational value and creates lasting memories for the kids, especially with the "Junior Wardens" deputization. This approach not only provides knowledge about conservation and wildlife but also fosters a sense of responsibility and pride among the children , parents and volunteers.

I am so grateful for their continued support! Thank you on behalf of the Founder Jim Holden and our board, we look forward to serving more children in 2025. To learn more and see all the pictures from our trips please go to www.fishforlife.org .

Thank you ,

Donna Kalez
Dana Wharf Sportfishing and Whale Watching
Board member Fish for Life

CALIFORNIA FISH AND GAME COMMISSION
RECEIVED 12/03/2024

Dear Commission President,

SAN FRANCISCO CA 940

I'm writing to tell you that we need to keep ghost nets out of the ocean, especially set gillnets. I care about this because: me and my family care alot about the wildlife so we need to support it too

Thanks from: Parker

& Lego First Team Canary 1

94244-2090

California Fish & Game Commission
P.O. Box 944209
Sacramento, CA
94222-2090

Dear Commission President,

SAN FRANCISCO CA 940
27 NOV 2024 PM 5 L

I'm writing to tell you that we need to keep ghost nets out of the ocean, especially set gillnets. I care about this because: I Love the ocean and all the creatures and want to keep them safe from harm.

Thanks from: Maddie K

& Lego First Team Canary 1

94244-2090

FOREVER
USA

California Fish & Game Commission
P.O. Box 944209
Sacramento, CA
94222-2090

Dear Commission President,

SAN FRANCISCO CA 940
27 NOV 2024 PM 5 L

FOREVER USA

I'm writing to tell you that we need to keep ghost nets out of the ocean, especially set gillnets. I care about this because:

I ♡ the ocean!

Thanks from: Megan C.

& Lego First Team Canary 1

California Fish & Game Commission
P.O. Box 944209
Sacramento, CA
94222-2090

94244-2090

Dear Commission President

SAN FRANCISCO CA 940
27 NOV 2024 PM 5 L

FOREVER USA

I'm writing to tell you that we need to keep ghost nets out of the ocean, especially set gillnets. I care about this because: I Love turtles and Batrays. Because nets hurt them

Thanks from: Joseph Kirchner

& Lego First Team Canary 1

California Fish & Game Commission
P.O. Box 944209
Sacramento, CA
94222-2090

94244-2090


Protect the Ocean from Ghost Nets!
"Ghost nets" are abandoned or lost fishing gear. They continue to capture and kill marine wildlife. They also block the sun from marine plants & get stuck on coral reefs. Ghost nets make up almost half of the Great Pacific Garbage Patch.


Protect the Ocean from Ghost Nets!


Protect the Ocean from Ghost Nets!
"Ghost nets" are abandoned or lost fishing gear. They continue to capture and kill marine wildlife. They also block the sun from marine plants & get stuck on coral reefs. Ghost nets make up almost half of the Great Pacific Garbage Patch.


"Ghost nets" are abandoned or lost fishing gear. They continue to capture and kill marine wildlife. They also block the sun from marine plants & get stuck on coral reefs. Ghost nets make up almost half of the Great Pacific Garbage Patch.

Outlook

FW: My comments for the public comments (item 2) at the upcoming CFGC meeting on 11 November ,2024

From Ashcraft, Susan@FGC <[redacted]>
Date Mon 12/02/2024 04:48 PM
To FGC <FGC@fgc.ca.gov>
Cc Miller-Henson, Melissa [redacted]>; richard@coastodian.org <richard@coastodian.org>

Forwarding for public comments.

Susan

Susan Ashcraft | Marine Advisor
California Fish and Game Commission

From: Richard James <richard@coastodian.org>
Sent: Monday, December 2, 2024 4:34 PM
To: Miller-Henson, Melissa [redacted]>; Ashcraft, Susan [redacted]
<[redacted]>
Subject: My comments for the public comments (item 2) at the upcoming CFGC meeting on 11 November ,2024

Hello,

Please accept the attached PDF file named "CFGC 2024.11.11 public comments.pdf" as my comments for the public comments (item 2) on that days' agenda.

I request that someone please acknowledge receipt of these comments, email is fine thank you.

richard james
coastodian.org

Plastic pollution is a serious problem worldwide, plastic in the ocean especially so.

We know that plastic is harming marine mammals, fish and birds in the ocean.

Yet, the shellfish industry embraces and deploys more and more toxic plastic gear each year. Gear that gets loose and floats off to sea. Gear that breaks down into microplastic, and is then ingested by all sorts of animals including oysters and humans!

Growers in Maine are working to grow oysters using wood instead of plastic for containers. This is the sort of innovation the planet needs. **Please promote safer alternatives to shellfish growers in California. (See photos at end)**

The leases for public trust tidelands where these oysters are grown are between the California Fish & Game Commission and the growers. Between THIS Commission, and the individual growers (tenants). **Your tenants need better supervision in order to ensure the environment is protected. (See photos at end showing what gets loose in Tomales Bay a couple weeks ago)**

As has been mentioned to me more than once, the California Department of Fish & Wildlife (CDFW) is responsible for enforcing the lease, as well as for protecting the environment. CDFW employees have, over the 15 years I have been learning about the shellfish industry, repeatedly explained how understaffed and underfunded they are. **Yet leases are made at ridiculously low prices. There is only ONE Tomales Bay, please price these leases accordingly!**

Nearly a decade ago, after I had collected over 2000 lost / abandoned shellfish containers from the shore of Tomales Bay, I filed a Public Records Access (PRA) request asking if any shellfish growers had ever been cited for littering in Tomales Bay. No was the answer. Sharing this incredible information with a game warden one day at Miller Park, wondering how this could be, the warden turned to me and said "A long time ago, we in Law Enforcement were told you are not to cite any shellfish growers for any violations you may see. Any such violations are NOT law enforcement matters, they are *Administrative Matters*, and you will forward them to us."

I have mentioned this numerous times at various CFGC and CDFW meetings over the years. Only once did someone reach out to me to discuss this matter. An Assistant Chief called me, heard what I was told, then told me he would get back to me.

After 2+ years, numerous phone calls and emails to him, with no replies, I learned that he had retired, never getting back to me.

Is this policy of letting the shellfish growers do as they please with immunity still in effect?

When will Best Management Practices be implemented?

When will a comprehensive security deposit / cleanup bond program be in place?

Thank you for your prompt attention to these long festering problems.

Richard James – coastodian.org

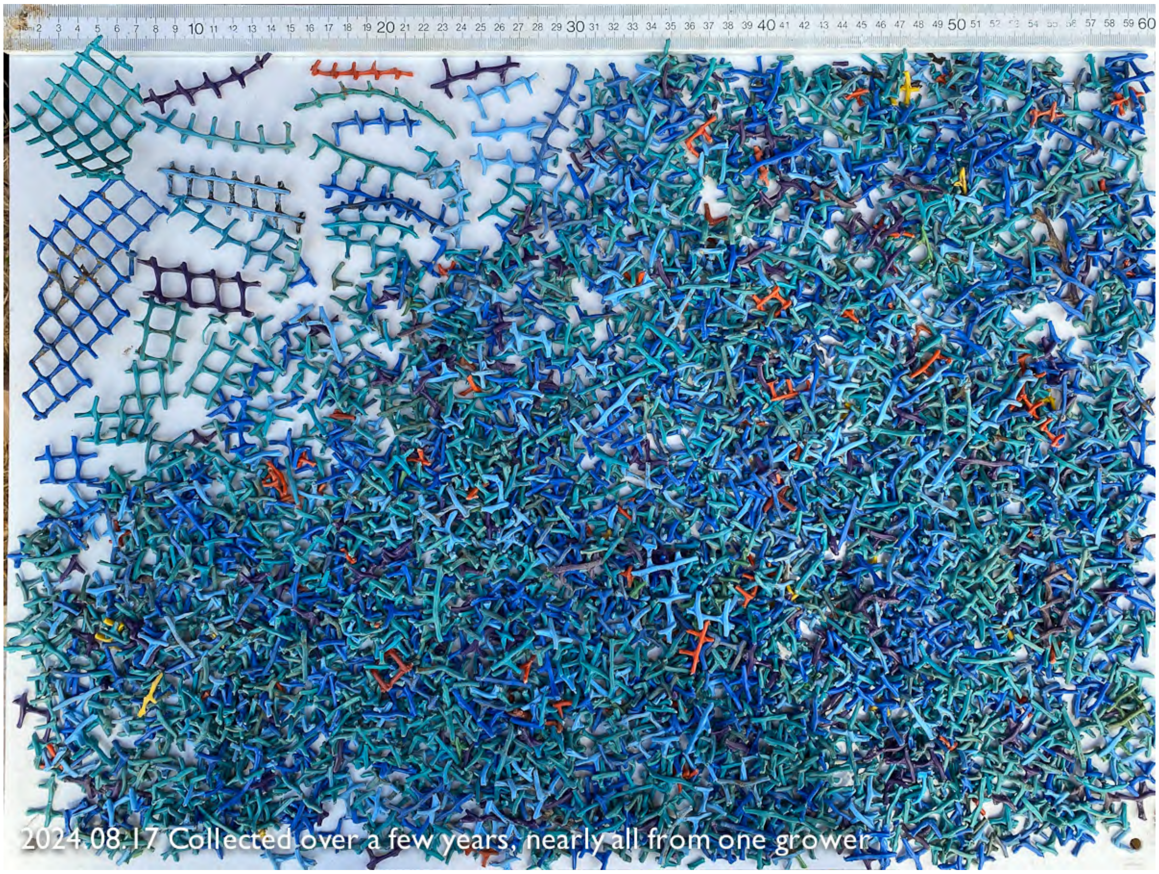
white cedar grow out containers at Northhaven Oyster Company, Maine

white cedar grow out containers at Northhaven Oyster Company, Maine

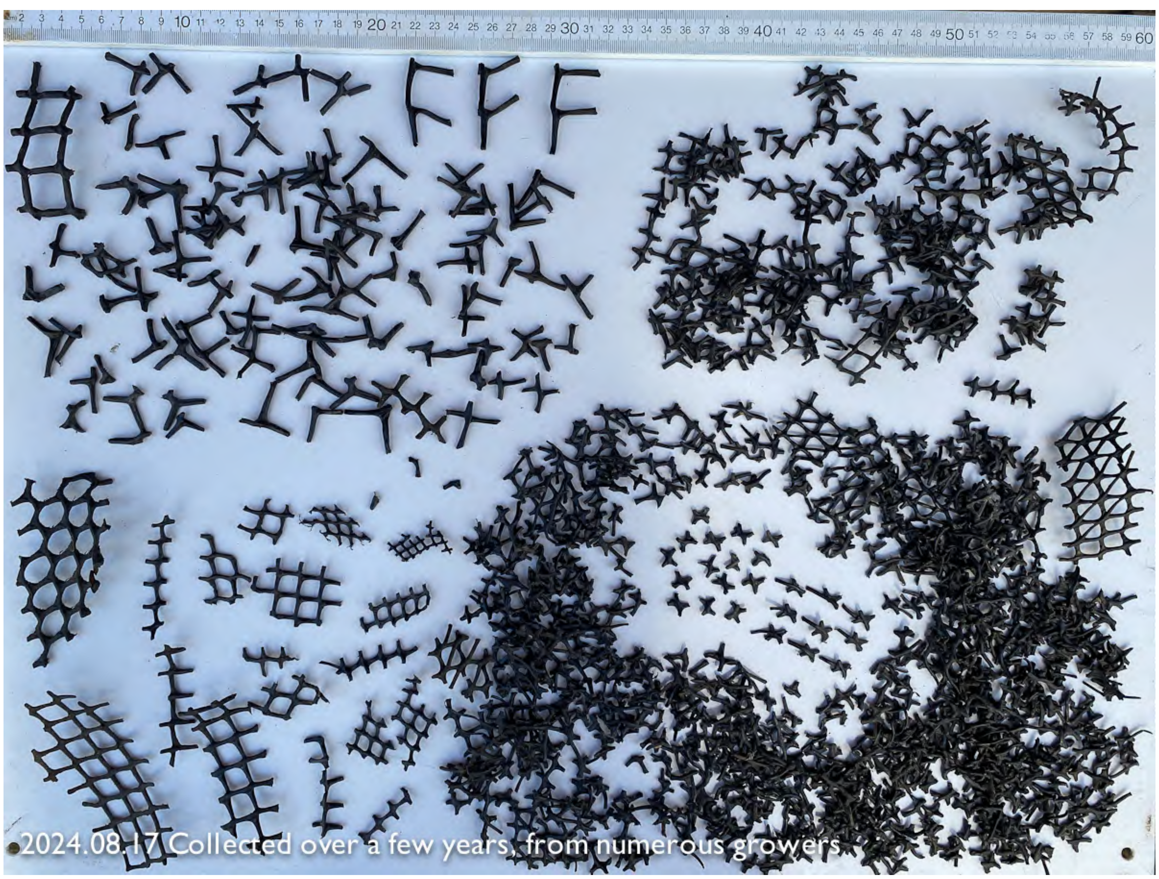
white cedar grow out containers at Northhaven Oyster Company, Maine


2024.11.27 - M-430-15 - post storm(s) shellfish debris high on shoreline


2024.11.27 - M-430-15 - post storm(s) shellfish debris high on shoreline



Oyster bag bits found from all over Tomales Bay, how much goes out to sea each year?



Lease payments: Tomales Bay leaseholders (2023)

Leasholder	Lease #	Acreage	2022		2023	
Charles Friend Oyster Company	M-430-04	**61.9**	53.00 /ac	3,281	60.50 /ac	3,745
Cove Mussel Company	M-430-06	**10**	50.00 /ac	500	50.00 /ac	500
Hog Island Oyster Company, Inc	M-430-10	**5**	100.00 /ac	500	100.00 /ac	500
	M-430-11	**5**	150.00 /ac	750	150.00 /ac	750
	M-430-12	**30**	62.25 /ac	1,868	71.25 /ac	2,138
	M-430-15	**128.2**	57.50 /ac	7,372	65.75 /ac	8,429
Marin Oyster Company, Inc.	M-430-02	**6**	114.75 /ac	689	131.25 /ac	788
	M-430-19	**25**	124.25 /ac	3,106	142.25 /ac	3,556
Point Reyes Oyster Company, Inc	M-430-13	**25**	57.25 /ac	1,431	65.50 /ac	1,638
	M-430-14	**6**	172.00 /ac	1,032	196.75 /ac	1,181
	M-430-17	**61.9**	57.25 /ac	3,544	65.50 /ac	4,054
Tomales Bay Oyster Company, LLC	M-430-05	**156**	62.25 /ac	9,711	71.25 /ac	11,115
Tomales Bay base rent				**$ 33,782**		**38,393**
Tomales Bay privilege taxes (estimated)				**$ 3,410**		**$ 3,892**
				$ 37,192		**42,285**

Lease payments: shellfish leaseholders outside Tomales Bay (2023)

Leasholder	Lease #	Acreage	2022		2023	
Grassy Bar Oyster Company, Inc	M-614-01, p1	**143**	62.25 /ac	8,902	71.25	10,189
	M-614-02	**15**	62.25 /ac	934	71.25	1,069
Morro Bay Oyster Company	M-614-01, p2	**134.5**	62.25 /ac	8,373	71.25	9,583
Santa Barbara Mariculture Company	M-653-02	**71.7**	53.00 /ac	3,800	60.75	4,356
Areas Outside Tomales base rent				**$ 22,008**		**$ 25,196**
Areas Outside Tomales privilege taxes (estimated)				**$ 848**		**$ 697**
				$ 22,857		**$ 25,893**

Total base rents from shellfish state leaseholders	**$ 55,791**	**$ 63,589**
Total estimated privilege taxes from state shellfish leaseholders	**$ 4,258**	**$ 4,589**
	$ 60,049	**$ 68,178**

884.2 ac

Escrow Accounts for State Water Bottom Leases

Tenant	Lease	Amount	2022 Clean-up Estimate	2023 Clean-up Estimate
Marin Oyster Company	M-430-02	$1,600.00	***$4,400**	$4,400
Charles Friend Oyster Company	M-430-04	$449.50	$20,000	$30,000
Tomales Bay Oyster Company	M-430-05	$100,000.00	$85,000	$60,000
Cove Mussel Company	M-430-06	$0.00	$0	$0
Hog Island Oyster Company	M-430-10	$97.47	***$60,000**	***$60,000**
Hog Island Oyster Company	M-430-11	$97.47	(combined estimate see Narrative)	(combined estimate see Narrative)
Hog Island Oyster Company	M-430-12	$500.00	(combined estimate see Narrative)	(combined estimate see Narrative)
Point Reyes Oyster Company	M-430-13	$363.00	$3,500	$3,500
Point Reyes Oyster Company	M-430-14	$300.00	$1,500	$1,500
Hog Island Oyster Company	M-430-15	$930.00	(combined estimate see Narrative)	(combined estimate see Narrative)
Point Reyes Oyster Company	M-430-17	$899.00	$10,000	$10,000
Marin Oyster Company	M-430-19	$1,019.00	***$6,000**	$6,000
Santa Barbara Mariculture	M-653-02	$3,600.00		
Grassy Bar Oyster Company Inc	M-614-02	$500.00	***$667**	$709
Grassy Bar Oyster Company Inc	M-614-01 pcl 1	$3,500.00	***$8,290**	$8,718
Morro Bay Oyster Company	M-614-01 pcl 2	$4,000.00	$3,000	$3,000
PharmerSea	M-654-03	$500.00	N/A	

*** Drafting updated Financial Surety agreement. 60 day notification to be sent to tenant.**

HIOC has Letter of Credi for $50,000.00 as of 2022