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Discussion

Environmental impact assessments should include rigorous scientific peer review

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ABSTRACT

Twenty USA states or jurisdictions and 125 nations have modeled national environmental policies after the National Environmental Policy Act. That act mandates that federal agencies initiate environmental impact statements (EISs) when substantive environmental or human health consequences are likely because of an agency action related to proposed development projects. The science used to inform the EIS process, however, does not require independent scientific peer review (ISPR) in the USA or most other nations. But ISPR is needed for governments to accurately inform the EIS decision-making and public reporting processes. Instead, science is routinely manipulated during EIS reviews to generate expedient project outcomes with substantially negative ecological, political, and long-term economic consequences. We provide four examples of EISs that lack ISPR, as well as four examples where reviews by independent scientists were helpful to improve agency decisions. We also recommend that independent scientists (no affiliation with the project proponents or agencies overseeing projects) be used to help assess potential environmental and socio-economic impacts, as well as offer appropriate risk assessments, study designs, and monitoring timeframes. We conclude that nations should convene formal reviews using independent scientists as a form of peer review in the EIS process.

1. Introduction

1.1. Short-changing the environmental review process is damaging to the environment

The bi-partisan USA Congress and President Richard Nixon enacted The National Environmental Policy Act (NEPA) in 1970, a global model in environmental assessment policies (USG, 2023). NEPA grew out of increased public awareness for the environment that culminated in the 1960s with its main purpose to help decision-makers estimate the true costs of proposed projects and thereby protect the human environment from major ecosystem impairment at taxpayer expenses (CEQ, 2021). NEPA required two actions. (1) It called for a Council for *Environmental* Quality (CEQ) within the office of the President. (2) It mandated that federal agencies initiate environmental impact statements (EISs) when substantive (i.e., unmitigable) environmental consequences are likely because of an agency action or proposed development project (USEPA, 2023a; USG, 2023). Under an EIS, federal agencies are required to systematically assess the environmental impacts of their proposed actions and consider alternative ways of accomplishing project proposals that are less damaging to the environment. Currently, 20 USA States or jurisdictions and 125 nations have enacted environmental policies modeled after NEPA (Eccleston, 2008; USEPA, 2023a).

Because of the vast numbers of potentially damaging actions, federal agencies routinely use Environmental Assessments (EAs; Eccleston, 2008). Relative to an EIS, an EA is a shorter public document providing

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documentation including analyses for determining whether a federal agency should indicate no significant environmental impact or prepare an EIS. EAs in the USA are much less comprehensive than those required under Canadian law, which resemble EISs and are focused on projects likely to cause substantial adverse environmental impacts, such as major new mines, marine terminals, highways, or waterways (CEAA, 2023). Likewise, they differ from the more rigorous EIAs required by the European Union for new major power stations, transportation projects, dams, or waste disposal facilities (EU, 2014).

1.2. A fundamental flaw in environmental impact statements (EIS)

We are a group of scientists involved for several decades in reviewing and preparing EISs for proposed projects affecting the environment (e.g., oil & gas, forestry, and mining) and planning for conservation and environmental protection in the USA and abroad. Our observations indicate persistent failure of the EIS process to accurately assess and predict likely harmful impacts to the human and natural environment, especially those involved in evaluating large areas and long timelines.

Many issues present in EIS production and review have been described over the last three decades in the USA and in similar processes globally (Eccleston, 2008). The baseline science, data collection, data handling, and data analysis are often low quality and rushed (Fairweather, 1994; Treweek, 1996; Thompson et al., 1997; Benkendorff, 1999; Ayles et al., 2004; Chang et al., 2013). Risk-assessment models are often poorly justified (Stern, 2013; Sheaves et al., 2016), then feed into impact determinations without identifying model assumptions and levels of uncertainties (Ortolano and Shepherd, 1995; Adelman, 2004; Duncan, 2008; Lees et al., 2016). Consequently, there is a long history of EIS predictions that have proven wrong after project completion. For example, the impacts of mining on water quality are well documented (e.g., Woody et al., 2010; Daniel et al., 2014; Hughes et al., 2016; Salvador et al., 2020), as is the long history of failures to accurately predict those impacts through the EIS process (Kuipers et al., 2006; Woody et al., 2010; CEC, 2022; see Section 2).

We provide our reasoning and examples herein for why independent scientific peer review (ISPR) is needed to effectively weigh environmental (environment, social, and economic) risks. An ISPR facilitates complying with statutes like NEPA regarding the likely impacts of actions that substantially affect local, regional, or global systems upon which humans depend. The EIS process is founded on the idea that an independent scientific assessment of proposed project alternatives and their potential impacts better inform final decisions. By independent, we mean environmental experts who are not affiliated financially with project outcomes.

1.3. The cover of "best available science"

As presently conducted, most EISs are flawed because agencies routinely use what they consider as the "best available science," which is often inadequate for at least five reasons. (1) The science is often not the best or current. (2) The project proponent ignores or downplays the internationally accepted precautionary principle and the burden of proof standard of no or least harm on the part of the project proponent (DellaSala et al., 2022). (3) Type-I over Type-II errors are emphasized (McGarvey and Marshall, 2005; Joly et al., 2010). (4) Data with insufficient statistical power are used. (5) Unreasonable *p* values are set (McGarvey, 2007; Wasserstein and Lazar, 2016). Also, courts routinely defer to agencies when contradictory evidence is presented in project appeals filed by environmental non-governmental organizations, including when those are backed by legal declarations from well-published independent scientists. Project assessments that focus narrowly on a single stressor or class of stressors, such as water quality (Rau, 2017; Hill et al., 2023), rather than the numerous environmental dimensions that support multiple components of healthy aquatic biota, are a special concern (Karr and Dudley, 1981; Karr, 1991; Karr et al., 2022). Likewise, assessments that focus on an immediate site, versus an entire drainage basin or airshed through time, are flawed from the start (FEMAT, 1993; Henjum et al., 1994; USEPA, 2023b).

The claim of "best available science" is routinely manipulated to generate pre-desired project outcomes often by "cherry picking" the science that supports a preconceived or desired outcome (McGarvey, 2007; Collard and Dempsey, 2022; Baker et al., 2023; Collard et al., 2023). Proposed projects frequently do not require "the federal government to use all practicable means to create and maintain conditions under which man and nature can exist in productive harmony" (USEPA, 2023a). Instead, agencies increasingly tend to sidestep more comprehensive EISs for overly simplistic EAs and by proposing projects that seek categorical exclusions for multiple projects deemed inconsequential when they truly may not be. We recognize that decision-making is ultimately influenced by political and economic realities (Dillon et al., 2018; Eccleston, 2008). However, the environment and the public interest are not well-served when science is manipulated to yield anticipated outcomes unsupported by ISPR. In other words, socio-economic and political decisions should be clearly separated from objective science and the need for evidence-based decisions (Hughes et al., 2021, 2023). Our criticism is not new (Lessing and Smosna, 1975; Schindler, 1976; Hilborn and Walters, 1981; Bella, 1987; Fairweather, 1989; Buckley, 1989, 1991; Peterson, 1993); however, the negative consequences are now magnified by the biodiversity and climate crises. In addition, federal agencies in the USA (and likely in other nations) often avoid more comprehensive analyses to bypass discoveries that are provided by more detailed environmental and economic analyses. Proponent agencies seek exemptions (e.g., categorical exclusions) under NEPA, asserting without evidence that projects are inconsequential when they are not so environmentally nor economically. A robust ISPR would limit flawed EIS and EA outcomes.

2. Four examples of flawed EISs

2.1. Trans-Alaska Pipeline System (TAPS)

An early example of an EIS is that developed for the Trans-Alaska Pipeline System (TAPS).

Large petroleum deposits were discovered in northern Alaska in 1968. After further exploration, a consortium of oil companies applied for a federal pipeline permit in 1969, planning to bury the pipeline and ship heated oil through it. But Native Alaskans, whose lands the pipeline would pass, sued in 1970. That issue was resolved in 1971 via the Alaska Native Claims Settlement Act at a price of $962 million plus 149 million acres of federal land returned to Native Alaskan entities. But then several environmental groups sued, stating that the pipeline would violate the Mineral Leasing Act. They also warned that the companies failed to consider alternative routes and such potential environmental impacts as oil spills, permafrost melting, earthquakes, erosion at >500 road-stream crossings, pipeline expansion and contraction, and fish and wildlife habitat losses. In response, the Department of Interior published an EIS in 1972. The 1300-km pipeline was completed, and oil began flowing in 1977. On March 24, 1989, the *Exxon Valdez* ran aground and spilled >4000 m^3 of oil into Prince William Sound (Fig. 1), killing billions of fish and thousands of birds and mammals (Piatt and Ford, 1996). The oil companies and the Department of Interior had failed to consider the risks of shipping oil in a single-hull tanker where free ice occurs and oil recovery is extremely difficult. The spill cost Exxon at least 1 billion USD, and the Prince William Sound ecosystem has yet to fully recover, at least partly because oil seeped into cobbles and PAHs (polycyclic aromatic hydrocarbons) in the oil had persistent embryotoxic and trophic cascade effects (Peterson et al., 2003; Incardona et al., 2015; Barron et al., 2020). Failing to embrace an ISPR and adequately consider and mitigate all the risks of moving oil across the seascape remains an economically and environmentally costly decision.

Fig. 1. The *Exxon Valdez* spilling oil after running aground in Prince William Sound (from: RGB Ventures/SuperStock/Alamy Stock Photo).

2.2. Pebble Mine (Bristol Bay, Alaska) draft EIS

The USA Army Corp of Engineer's Pebble Mine draft EIS (ACOE, 2019) failed to consider ISPR and displays more of the inadequacies in NEPA analysis and implementation by USA federal agencies. Located on State land in Alaska's Bristol Bay watershed, the mineralized region is 13.5 km^2 by 600–1200-m deep (Woody, 2018). The initially proposed Pebble Mine would have required a 760-m deep by 3.7-km wide open-pit with a 166-m high tailings dam (Chambers et al., 2012). During mine operation, the treatment and discharge of 54 billion L of water annually would be required (ACOE, 2020). Underground mining of additional ore, not analyzed in the EIS, would almost certainly follow the open pit mining phase, and would require additional tailings facilities.

The pristine rivers draining the mine claim are essential to salmon and flow into Bristol Bay, home to the world's largest wild sockeye salmon (*Oncorhynchus nerka*) fishery (Woody, 2018). Its seafood industry

Fig. 2. Example of a catastrophic tailings dam failure. Tailings from the Polley Mine spill deposited over Hazeltine Creek (https://watershedsentinel.ca/articles/mount-polley-mine-is-still-pumping-waste-into-quesnel-lake/). Before the spill, the creek was 5-m wide, with a cobble and gravel bed and forested riparian zone (Byrne et al., 2018).

employs thousands of people and generates millions of USD in sales annually. Indigenous peoples have subsisted on salmon from the rivers for millennia; salmon comprise 60–80% of their traditional harvest and have averaged >100,000 salmon annually (Woody et al., 2010). Metal mines have a long history of point-source water pollution and tailings pond failures (Kuipers et al., 2006; Woody et al., 2010; Bowker and Chambers, 2017; CEC, 2023), some that have been catastrophic (e.g., Escobar, 2015; Virgilio et al., 2020). The USA Environmental Protection Agency's peer-reviewed Bristol Bay Watershed Assessment found that the mine could have "unacceptable adverse effects on fishery areas" (USEPA, 2014).

Nonetheless, in its EIS the ACOE, 2020 did not even consider a catastrophic tailings dam failure, despite recent calamities in Brazil and at the Mount Polley facility in nearby British Columbia (Fig. 2). Analysis of catastrophic dam failures is necessary to protect workers and the public, to ensure that appropriate warning systems and evacuation plans are developed, and to avoid building facilities in areas that could be inundated. Finally, the ACOE concluded that mining would not have "a measurable effect" (ACOE, 2020) on Bristol Bay fisheries.

The USEPA (2019) had called attention to a litany of the ACOE's draft Pebble Mine EIS problems. Those included that the draft lacked details regarding waste-rock chemical characterization, ground-water modeling, wetland and stream impacts, marine impacts, mine dewatering, tailings dam and water management, ground water seepage, water treatment plant operations, fishery impacts, mine reclamation, environmental monitoring, compensatory mitigation, and risks of tailings facility failures.

In November 2020, the ACOE (2020) reversed its prior draft EIS, which asserted that the mine would have no substantive effects, and denied Pebble Mine a permit, stating that its plan failed to "comply with Clean Water Act guidelines," was "contrary to the public interest," and offered an "insufficient amount of compensatory mitigation." Following appeals, the USEPA (2023b) also denied Pebble Mine a permit to use the Bristol Bay watershed for disposing of mine dredged or fill material under Clean Water Act Section 404(c). In a 280-page document with 340 peer-reviewed references, citing science-based decisions, the USEPA deemed the mines would cause unacceptable harm to salmon. Thus, despite an inadequate draft EIS and after over 20 y of prospecting, litigation, research, hearings, and subsequent ISPR, the Pebble Mine was effectively defeated. But that should have been obvious even before the draft EIS to any trained ecologist, fishery biologist, or environmental scientist. It was simply too vulnerable a place for a mega-mine.

2.3. Alaska's general mine EISs

Hardrock mines use and generate large volumes of hazardous and toxic materials that have substantial environmental and public health risk when spilled. These spills include processing chemicals (e.g., cyanide solution), ore concentrates (e.g., heavy metals), fuels, or mine tailings. Mining EISs rarely quantitatively address spill risks, and generally only consider spills related to transportation. The Alaska Department of Environmental Conservation (ADEC) maintains a thorough and publicly accessible database of mine permitting documents and reported spills. For the five major hardrock Alaska mines (Pogo, Greens Creek, Kensington, Fort Knox/True North, and Red Dog), the transportation spills model used by USEPA (2014) would have predicted a total of 4.3 truck accidents with hazardous material spills (Fig. 3A) if such analyses had been shown for all five mines. That number of spills (N) was based on the predicted number of kilometers traveled (T) for all five mines from their beginning production dates through 2020 and a spill rate per kilometer (R) using $N = RT$. Lubetkin (2022) compared the spill predictions in permitting documents versus spill records for 1995–2020 from ADEC (2021) records and showed that there were 1004 total transportation-related spills at all five mines, resulting in aggregate totals of 127 m^3 and 803,347 kg of hazardous materials spilled (Fig. 3A; Lubetkin, 2022).

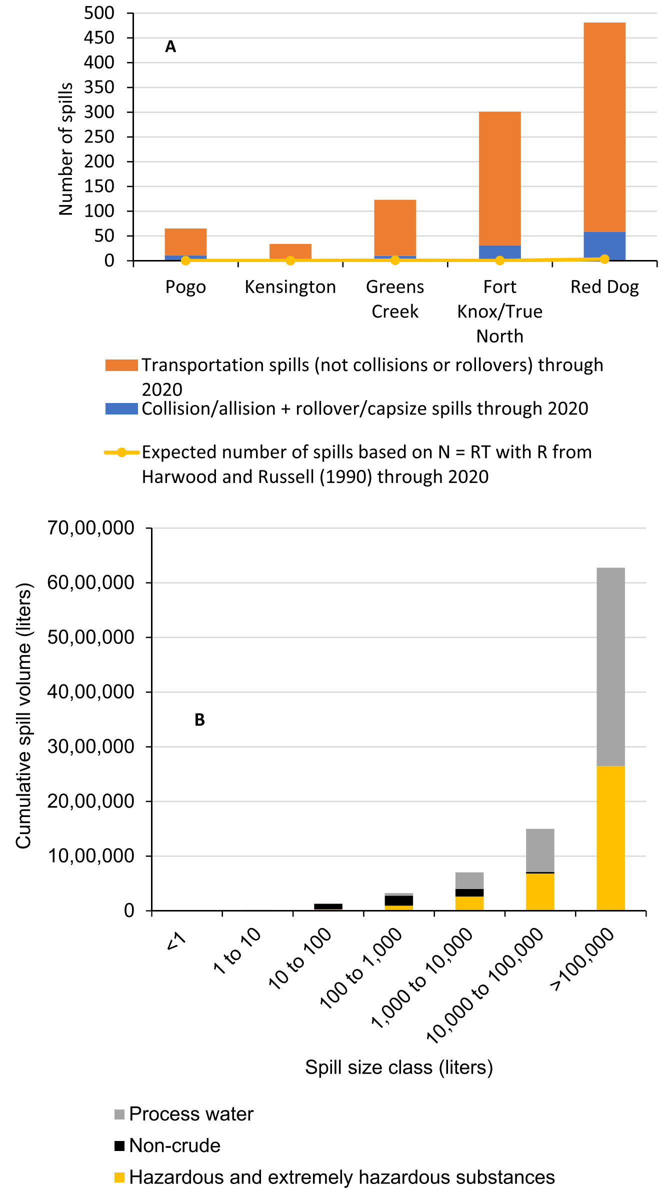

Fig. 3. (**A**) Number of transportation spills at five Alaskan mines (Pogo, Greens Creek, Kensington, Fort Knox/True North, and Red Dog); and (**B**) spill volumes by substance class from all sources and causes at those five mines from their beginning production dates through 2020 (Lubetkin, 2022; Harwood and Russell, 1990).

However, transportation spills were a small portion of the total number of spills reported at the five mines. The ADEC database for the five hardrock mines documented more than 8150 total spill incidents, releasing >8,934,000 L and >875,433 kg of hazardous materials since 1995 (Fig. 3B; Lubetkin, 2022). Many of the substances that were listed in the ADEC spills database were not mentioned in the EISs as part of reagent lists, fuels, or tailings that could be released (Lubetkin, 2022).

Within the EISs, spills of individual substances were described as low-probability events, and the aggregate, cumulative risks and impacts of all the hazardous material spills from all sources and causes were not addressed. Both the EISs and EAs lacked explicit, complete, and quantitative reagents lists, as well as specifications of other chemicals used for blasting, water treatment, and spill mitigation, that would be considered as hazardous materials being transported to or from the mine or used on-site. Based on our general concerns, we assert that mining EISs should be improved in seven ways.

- Include explicit, complete, and quantitative hazardous material lists for substances transported to or from the mine or used on-site.
- Provide complete descriptions of the transportation methods, load sizes, and transportation frequencies for the hazardous materials.
- Include newly built mine roads as well as the origins and destinations of the hazardous materials in the transportation corridor modeling.
- Ensure realistic quantitative transportation spill-risk estimates for the aggregated total of trips and the whole mine operation's cumulative hazardous materials spill-risks based on updated available evidence.
- Provide detailed transportation spill risk models, with updated risk-rates and location-specific descriptions of the transportation corridor.
- Model the multiple transportation-related releases, as well as likely accidents.
- Enumerate the numbers of expected spills, even if those estimates are minimum values, because there are insufficient data to model all potential spill causes (i.e., apply the precautionary principle).

Spill risks were the only aspect considered in the EISs and EAs of the five mines (Fig. 3A) examined by Lubetkin (2022), but they exemplify how decision-makers and community members receive insufficient representations of the environmental consequences of approving large mines. The ISPR by Lubetkin (2022) showed that the spill-risk predictions in the EISs and EAs were incomplete, inaccurate, or nonexistent. Current risk-assessments in EISs for Alaskan mines do not measure up to the main objectives of an informed EIS, which are: (1) estimate potential consequences of project impacts, and (2) inform stakeholders and decision makers how to mitigate those consequences.

2.4. *Characterizing the probability of catastrophic discharge events on the outer continental shelf*

Even when risks are calculated using defensible models, the results may not be put into context such that lay people and decision makers will understand their implications, especially if those persons are unfamiliar with statistical terminology. For example, consider the Bureau of Ocean Energy Management's 2019–2024 National Outer Continental Shelf Oil and Gas Leasing Draft Proposed Program (BOEM, 2018) treatment of the probability of catastrophic discharge events (CDEs). The estimated return periods ranged from 39 y for spills >150,000 barrels (bbl; 23,848 m^3) to 770 y for spills >10,000,000 bbl (1,589,873 m^3; Tab le 7.4 in BOEM, 2018).

Like flood-risk estimates for rivers (Gordon et al., 1992), spills are stochastic events that do not occur with regularity (Friel et al., 1993). An event such as the 2010 *Deepwater Horizon* disaster that released 4.9 million bbl (779,038 m^3) may be estimated to have a return period of >400 y, but that does not mean it can then be safely assumed that the next such event will not occur until after the year 2400. Instead, the return period for a spill of a given volume can be used to find the probability of at least one spill in each time period. For example, if the return period for a specific spill volume is 165 y, then that spill size (or larger) "is most likely to occur once in 165 y, and every year has a chance of occurring of 0.6% (=1/165)" (Ji et al., 2021). Having an estimate of the probability of occurrence in a single year facilitates calculating the probability of at least one occurrence within a specified number of years using the binomial distribution, assuming that the events are independent and identically distributed across all years (Lubetkin, unpublished data).

For example, if the return period for a spill is 165 y, then the probability of having a spill in one year is 1/165 as stated above and the probability of having zero spills in one year is 1–1/165. In that case, the probability of zero spills in two years is $(1–1/165)^2$ and the probability of having at least one spill in two years is $1 – (1–1/165)^2$. If the return period for a >1,000,000 bbl (158,987 m^3) spill is 165 years (Ji et al., 2014a,b) and the exposure is 30 years, then the probability of at least one spill >1,000,000 bbl $= 1 – (1–1/165)^{30} = 16.7\%$. Analogous computations can be used to find the probability of other spill volumes with their return periods for different amounts of exposure. Thus, using the return

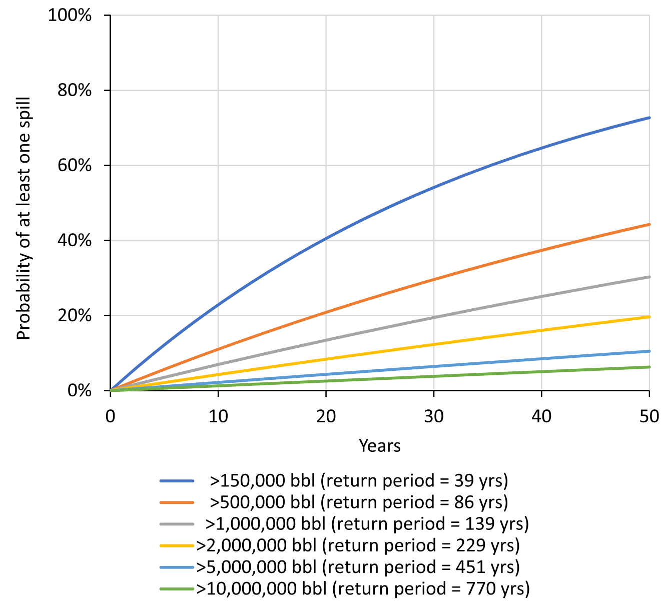

Fig. 4. Outer Continental Shelf spill probabilities for various return periods for spills >150,000 bbl to >10,000,000 bbl (data from BOEM, 2018). One barrel = 0.16 m^3.

periods given in BOEM (2018) for several spill sizes, probabilities can be calculated for various years of production (Fig. 4). BOEM (2018) only presented the return periods and described CDEs as "statistically unexpected" events that "would be considered well outside the normal range of probability" for the 2019–2024 proposed program. But BOEM (2018) showed no calculations for the probability of a CDE for either the 2019–2024 proposed program nor for the outer continental shelf's extant production. A quantitative ISPR (Lubetkin, unpublished data) came to much different, and more realistic, conclusions (Fig. 4).

3. Independent scientific peer review: case study examples

3.1. *Forest ecosystem management assessment team (FEMAT) and the Northwest Forest Plan (NWFP)*

In the 1990s, regional protests over old-growth logging, federal timber-sale injunctions, and the threatened northern spotted owl (*Strix occidentalis caurina*) led to a court injunction on logging by USA District Court Judge William Dwyer. He found that federal agencies were not complying with the population viability standard of the National Forest Management Act and directed the USA Forest Service and the Bureau of Land Management to adopt the landmark Northwest Forest Plan (DellaSala et al., 2015). The plan was kicked off at a Northwest Forest summit in 1993 attended by President Bill Clinton, Vice-President Al Gore, and several cabinet-level officials. Its principal objective, as stated by President Clinton, was to produce a plan that would be "insofar as we are wise enough to know, scientifically sound, ecologically credible, and legally responsible" (FEMAT, 1993).

To ensure that the plan had the scientific foundations needed to comply with the injunction and the President's wishes, six federal agencies involved in the region's forests and wildlife management convened a scientific panel. The panel was charged with developing the justifications and alternatives for ecosystem management, biodiversity conservation, and timber supply (FEMAT, 1993). A key component of the resulting forest plan was the establishment of unlogged forest buffers along streams using buffer widths based on habitat factors needed to support salmonids (FEMAT, 1993; Olson et al., 2007, Fig. 5). The buffer widths were defined as two potential tree heights (100 m) on both sides of streams supporting fish and one tree height (50 m) on both sides of streams lacking fish. Since the development of this standard, state

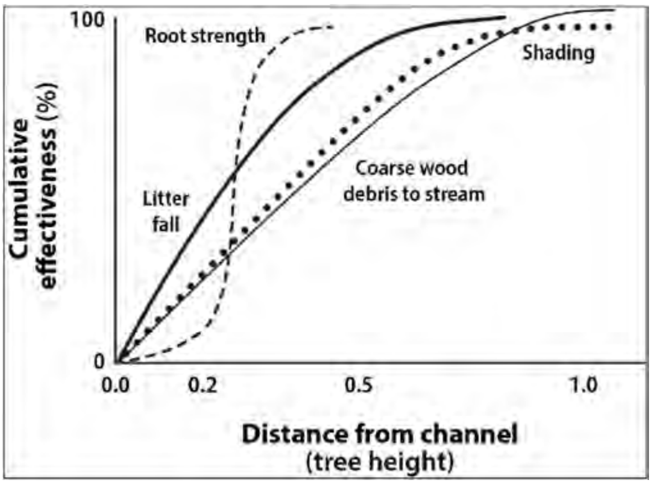

Fig. 5. Cumulative effectiveness of habitat factors contributing to instream habitat conditions for supporting salmonids (FEMAT, 1993).

agencies in the region have established similar (but narrower) stream-side buffers to protect the physical, chemical, and biological conditions of forest streams (Knutson and Naef, 1997; Quinn et al., 2020). Similar buffers have been recommended for agricultural streams (Sweeney and Newbold, 2014; Hughes and Vadas, 2021) and are required for Brazilian streams (Brasil, 2012).

The Northwest Forest Plan is a 100-y plan to recover old forest ecosystems that support imperiled species as well as the transition of rural communities from logging older forests to less unstable economies. As such it is a legal compromise—based partly on ISPR–amongst many competing interests, and it continues to regulate forest management in the USA Pacific Northwest to a degree. The Plan slowed logging of old trees on federal forestlands and led to a quantitative forest monitoring and assessment program (AREMP, 2023; Dunham et al., 2023). However, the spotted owl has continued to decline because of increased competition with non-native barred owls (*Strix varia*; Rockweit et al., 2023) and the climate crisis. Threatened salmon species have not recovered in the Plan area, being limited by the climate crisis, stream fragmentation, and habitat degradation, mainly on nonfederal lands (Gaines et al., 2022). However, without the ISPR that led to the Plan and improved forest management, those additional stressors would have had even more negative impacts on forest ecosystems.

Whereas the NWFP has withstood multiple attempts to weaken its conservation framework for over three decades, it is scheduled for a major revision in 2024. Rather than adopting a FEMAT approach, the US Forest Service convened a stakeholder team consisting of interest groups from timber, conservation, development, tribes, and some scientists. For the most part, that team has ignored the underlining foundation of the original plan such as reserve design, connectivity, spotted owl habitat, and salmonid habitat. In addition, it is ignoring more recent concerns over carbon accounting when assessing older forest stands and fluxes from logging and fires. Thus, the science approach of FEMAT was replaced by an untested stakeholder-driven process versus the original Plan's emphasis on species and old forest viability.

3.2. Eastside Forest Scientific Society Panel

In 1992, a FEMAT-like process was lacking for managing the 6 million ha in 10 national forests east of the Cascades in Oregon and Washington. That shortcoming stimulated a bipartisan group of seven Congressional members to approach the American Fisheries Society, American Ornithologists Union, The Ecological Society of America, Society for Conservation Biology, and The Wildlife Society to form the Eastside Forest Scientific Society Panel (EFSSP). The EFSSP had two mandates. (1) Identify areas where logging could compromise long-term ecological viability of forest, fisheries, and associated values. (2) Recommend management guidelines to protect those critical areas in the interim while a long-term conservation plan would be developed.

Based on 50 map layers of environmental conditions, the EFSSP provided detailed maps and tabulations of natural resource conditions on six major topics for each national forest (Henjum et al., 1994). They first identified areas of existing old-growth forest, located watersheds critical for fisheries, and mapped roads, streams, and roadless areas by size. Next, they reviewed existing knowledge on the status of fish and terrestrial species likely to be altered by forest management and assessed the status of habitats needed by species of concern.

The EFSSP estimated that old-growth forests covered <15% of their original area in lower elevation forests and that continued logging in unprotected areas would reduce old-growth of all forest types to <10% of forest area in the region, thereby challenging their sustainability. Fisheries and riparian areas were generally in poor condition and the status of numerous terrestrial species was of concern. EFSSP recommended 11 measures to ensure "interim" protection of species and ecosystems as part of a long-term planning process for those national forests.

- Allow no logging of late-successional (mature) and old-growth stands (LS/OG).
- Cut no trees older than 150 years or with ≥20" (50 cm) diameter at breast height (dbh).
- Allow no logging of ponderosa pine stands.
- Allow no logging, road building, or mining in designated aquatic diversity areas.
- Allow no new roads or logging in roadless regions >1000 acres (400 ha).
- Establish protected corridors along streams, rivers, lakes, and wetlands.
- Allow no logging or mining in fragile, erosion-prone areas unless ISPR conclusively demonstrates that it will not degrade soils, release sediment to streams, or slow forest regeneration.
- Allow no livestock grazing in riparian areas unless ISPR conclusively demonstrates that it will not damage those areas.
- Establish a panel with broad expertise to develop long-term management guidelines to aid forest capacity to resist drought, crown fires, and catastrophic disease outbreaks.
- Establish a panel to develop a coordinated strategy for restoring the health and integrity of eastside landscape ecosystems and the processes that they depend on.
- Establish a comprehensive quantitative biomonitoring and bioassessment program.

The ISPR was successful in initially producing an ecological monitoring program (PIBOMP, 2023; Henderson et al., 2005) and interim protections for large (>50 cm) trees that stood for nearly two decades. However, the Trump administration rescinded the rule in favor of logging trees up to 150 years old (up to 76 cm dbh) for purported restoration, fire risk reduction, and resilience purposes. That rule change remains controversial as the U.S. Forest Service only cited science that supported the change (Johnston et al., 2021), whereas others have pointed to flaws in that approach (Mildrexler et al., 2023). Old-growth forests have declined to <3% of pre-settlement amounts and only occur in small, isolated stands (Youngblood, 2001). Yet, logging of large trees recovering from past logging were once again targeted. In 2022, six conservation groups sued the Forest Service for violating several federal listed species and forest laws, including aquatic species impacts. In 2023 and 2024, two different federal judges upheld their suit, deeming the agency actions arbitrary and capricious and ordering an EIS. That new EIS should include ISPR.

3.3. Bristol Bay Watershed Assessment

Rather than focusing solely on the Pebble Mine, USEPA's Bristol Bay

Watershed Assessment (USEPA, 2014), written by 16 federal, state, private, and university scientists, provided a comprehensive evaluation of mining risks to Bristol Bay fishery resources. It addressed both the 25-100-y mine development and operation phase as well as the post-mining phase, during which the site would be monitored, and water and solid-waste treatment would be continued in perpetuity. Mining of other copper deposits in the mining district would require the same monitoring and waste treatment. Assuming collection and effective treatment of all water, and no failures, fishery impacts would result from the loss of 90–151 km of salmonid spawning or rearing habitat. Over the long term, four to 10 streams would lose fish passage and be degraded from road-culvert jams, washouts, and erosion. One to two pipeline failures would likely occur over the mine life, which would release toxic water and sediments, kill fish and invertebrates, and persist for decades before settling into Iliamna Lake. Likely failures of the water and waste collection and treatment systems would result in short-term to perpetual toxic releases. A tailings spill would eliminate 38–48% of the salmon run in the Nushagak River and trout populations would be lost for decades (see Fig. 2). USEPA (2014) formed the scientific foundation for EPA's opposition to the ACOE, 2020 draft EIS that permitted the Pebble Mine and its support of USEPA (2023b) that prohibited it.

Unlike the Pebble Mine EIS (ACOE, 2020), which concluded that there would be no significant impact to fisheries in Bristol Bay resulting from the mine, the Bristol Bay Watershed Assessment found that there would be a significant risk of harm to the fisheries. The Bristol Bay Watershed Assessment underwent several rounds of peer review before the final report was issued. The scientific studies that formed the basis for the Assessment and its conclusions were individually peer reviewed. None of the scientific studies supporting the Pebble Mine EIS were peer reviewed. It is logical to conclude that the more thorough and rigorous application of science in the Bristol Bay Watershed Assessment led to significantly different conclusions about risk to the fisheries than those in the Pebble Mine EIS.

3.4. *Klamath river (Oregon, California) EIS*

The Klamath River was once a major salmon producer (Gresh et al., 2000). Prior to dam construction beginning in 1918, it produced 650, 000–1,000,000 fish. Its upper basin sits in the relatively dry Eastern Cascades Slopes and Foothills Ecoregion of Oregon, where ranching and irrigated agriculture are the major water withdrawals. Further downstream, the Klamath flows through the Klamath Mountains Ecoregion in California, which is dominated by coniferous forest and where logging is a major industry. Four upriver dams blocked salmon passage for over 100 y (Fig. 6); conflicts over water rights resulted in crop losses in 2001 to protect salmon, followed by tens of thousands of salmon deaths in 2002 to protect irrigators. As part of its relicensing agreement in 2007, PacifiCorp, the owner and operator of the four dams, had to install fish passage facilities and make other improvements or remove the dams. PacifiCorp determined that dam removal would be less expensive than continuing to operate the dams and entered into a formal agreement with California, Oregon, the Department of the Interior, the National Marine Fisheries Service, and the Karuk and Yurok Tribes in 2016 to remove the dams. Following lengthy ISPR by engineers, geologists, hydrologists, fishery and wildlife scientists, botanists, water quality biologists, sociologists, and economists, a final EIS was produced by the Federal Energy Regulatory Commission (FERC, 2022). The first dam, Copco 2, was removed in 2023; the remaining three dams are scheduled for removal by 2025 (Davidson, 2023). This will be the largest dam decommissioning and salmon rehabilitation project in the history of the USA and will also begin restoring justice to the Tribes who have depended on salmon for their existence for millennia.

Fig. 6. Iron Gate Dam (53-m high, 226-m long; from Michael Wier, Klamath River Renewal Corporation).

4. Independent peer review benefits

Based on our review of some exemplary EIS projects, we assert that the most important flaw in the EIS process is the failure to require ISPR. Scientific journal manuscripts require ISPR before acceptance for publication. Reports by the USA Environmental Protection Agency's Science Advisory Board and the National Academies of Sciences, Engineering, and Medicine require ISPR. Yet, the science used to inform the EIS process does not require ISPR. But ISPR is needed to accurately inform the EIS decision-making, allow for accountability determination in case of compliance failures, and facilitate the public reporting process. Without formal review by independent scientific experts, attorneys representing NGOs are justified in challenging inappropriate analyses of the predicted project impacts.

We emphasize that best available science depends on critical reviews by independent scientists (Karr and Chu, 1999), economists (ECONorthwest, 2019), and statisticians (Utts, 2021) who are not affiliated financially with project outcomes or agency funding contracts. Objective reviewers with knowledge of the relevant science can assess whether project proponents have properly considered short-versus long-term planning horizons; costs of deferred regulations; potential ecological, social, and economic consequences; cumulative effects; and advances in scientific understanding, among others. Federal agencies often make harmful environmental decisions based on a burden-of-proof standard that underestimates impacts and can result in environmental disasters, such as from mining and fossil fuel extraction (Woody et al., 2010; Hughes et al., 2016; Bowker, 2021). This means that environmental organizations must try to correct those shortcomings via project appeals and litigation (Whittaker and Goldman, 2021; Baker et al., 2023), or taxpayer-funded rehabilitation (USEPA, 2000, 2004). Notably, in a survey of 22 recent EISs, only 27.6% (3672 of 13,291) of the references cited were of articles from peer-reviewed journals (Lubetkin, 2020). ISPR and subsequent evaluation and corrective responses to the peer-review findings help ensure transparency, scientific credibility, and accountability.

When the decision in an EIS is delayed on legal appeal for years because of inadequate, biased science, or inconsistent science and conclusions about the risk to the environment and human health, many of those involved pay a high price for wasted effort and time (Eccleston, 2008). The resulting inefficiencies harm citizens, taxpayers, affected communities, agency personnel, industry, and investors, as well as the environment. Poorly applied science and engineering have systemic consequences, including spectacularly expensive failed plans and project proposals, often with unanticipated or undisclosed harm to the environment and human health (Kuipers et al., 2006; Hughes et al., 2016; Salvador et al., 2020).

This is not surprising. Without ISPR and an impartial evaluation as to whether high quality, objective scientific processes were followed by the EIS proponent, there is little incentive for agencies to articulate uncertainties, risks, and likely impacts, and the process naturally becomes siloed by tunnel vision and driven by project proponent preferences. In general, "good science is not, as some have cynically suggested, merely in the eye of the beholder, nor is it whatever technical information can be cobbled together to support one's predetermined position" (Elliott, 2003, p. 46). This is also certainly true for an EIS or an EA as well as projects that bypass the formal review process via "categorical exclusions" under NEPA when realistically those are anything but nonconsequential (DellaSala et al., 2022).

5. Recommendations

5.1. Project pre-proposals

Often EISs are hampered by the quality of available data. Ideally, project pre-proposals and scoping should incorporate early interaction amongst developers, regulators, the public, and independent scientists to list likely concerns regarding potential ecological and socio-economic impacts, as well as offer appropriate risk assessments, study designs, and monitoring methodologies and timeframes (Eccleston, 2008; Noble, 2020, Fig. 7). Monitoring is often neglected or poorly designed and funded in initial and subsequent EAs and planning, which precludes effective adaptive management (Hughes et al., 2000; Maas-Hebner et al., 2016). In addition, agencies and proponents tend to be married to their ideas and reluctant to change if the first round of planning is less robust than that required in an EIS. Thus, an additional step should focus on the study designs needed to improve the initial- and later-stage science of impact assessment and adaptive management. Particularly important is having adequate sample sizes and statistical power for relevant studies, to minimize Type-II errors that falsely infer no impacts (McGarvey, 2007; Utts, 2021; Hughes et al., 2023), and to ensure that statistical and biological significance are not falsely synonymized (Possingham et al., 2001; Vadas et al., 2022). Conversely, erroneous reporting of statistically significant results resulting from pseudoreplication must be avoided (Perneger and Combescure, 2017; Utts, 2021; Vadas et al., 2022). In many USA and global cases, the impacts and risk assessments of prior, similar projects—and what went wrong with them—are available in the scientific literature and on-line (e.g., Kuipers et al., 2006; Bowker and Chambers, 2017; Bowker, 2021; CEC, 2022).

5.2. Project EIS or EA

If the questions asked in the initial scoping phase are answered satisfactorily, an EIS or EA peer review could take many forms (Eccleston, 2008). Other countries have successfully implemented such reviews. For example, under the Canadian Impact Assessment Act (Government of Canada, 2019), the Minister of Environment and Climate Change may determine that it is in the public interest to refer the assessment to an independent review panel (CEAA, 2023). Such a review panel is a group of independent and impartial experts appointed by the Minister to: (1) conduct the environmental assessment; and (2) make conclusions and recommendations to the Minister. The review panel members must have knowledge or experience relative to the anticipated environmental, social, and economic effects of a project. They must also be objective and free from any apparent financial conflict of interest relative to the project or their own research funding source, such as being under contract for the proposing agency or entity. Some of them should be environmentally concerned scientists, economists, and sociologists. Because of the amount of time required by the peer-reviewers plus the need for independence, the proponent and the oversight agency should fund the reviewers via an independent contractor as several of us have experienced (Table 1).

We encourage the USA Council on Environmental Quality (CEQ) and similar bodies in other nations to adopt the kind of thorough review processes exemplified in Section 3 and Fig. 7, as a component of the EIS process. The extent and complexity of the ISPR should vary with the potential extent and cumulative effects of the project, which are determined during the scoping process (Eccleston, 2008). Public comment on the EIS or EA scoping that is prepared by the cooperating agencies should identify most of the areas requiring peer review of the technical reports used to establish EIS or EA conclusions. Although this adds additional

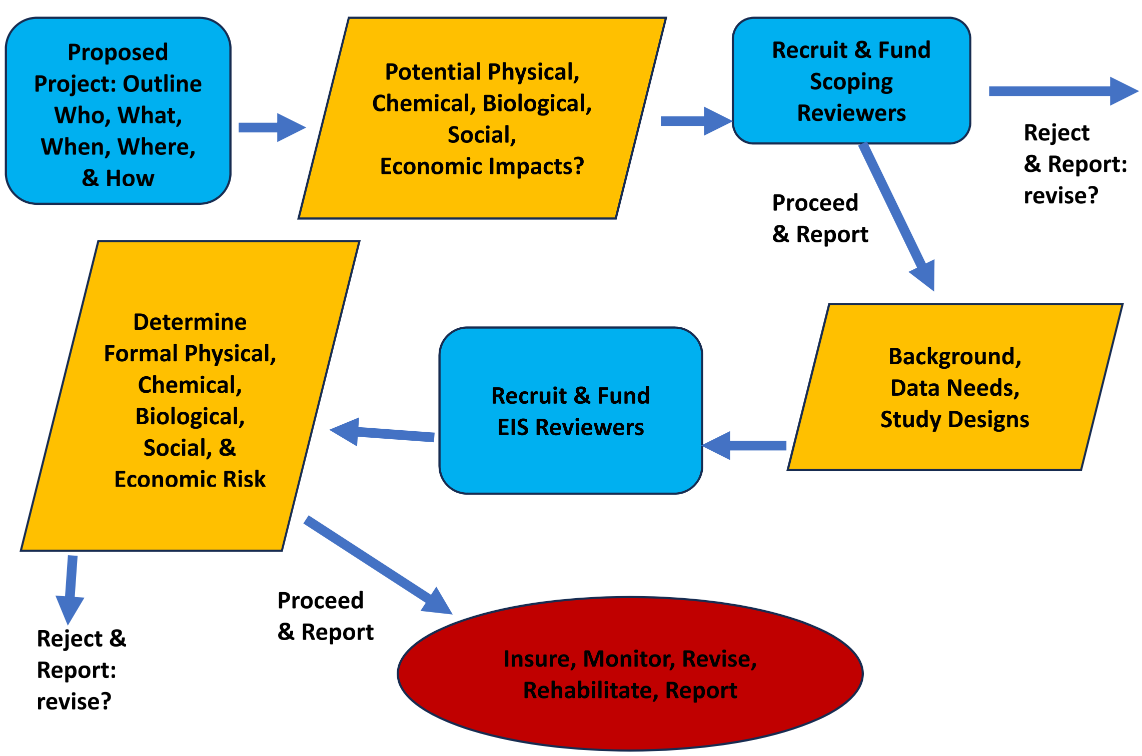

Fig. 7. Recommended steps in EIS independent scientific peer-review process.

Table 1
Examples of scientific peer reviews, their funding sources, and durations.

Name	Funder	Duration	Reference
Aquatic Conservation Strategy	Coast Range Association	2-day meeting 2-month writing	Frissell et al. (2014)
Ecological Conditions in Hydropower Basins	Companhia Energética de Minas Gerais	5-years	Callisto et al. (2014)
European Fish Index	University of Natural Resources & Life Sciences, Vienna	2 1-week meetings	EFI+ CONSORTIUM (2009)
EMAP Indicator Workshop	USEPA	4-day meeting 1-month writing	Hughes (1993)
Gulf of Mexico Catastrophe	Earthjustice	6 months	Lubetkin (2020)
Kissimmee River Restoration	South Florida Water Management District	4-day meeting 2-years writing	Loftin et al. (1988)
Mining & Fossil Fuel Extraction	Not funded	2-years writing	Hughes et al. (2016)
Mining Retrospective	Natl. Parks Cons. Assoc., Tanana Chiefs, Earthworks, Brooks Range	9 months	Lubetkin (2022)
National Wildlife Refuge System	Indiana University Schools of Law and Public & Environmental Affairs; US Fish & Wildlife Service	1-week meeting 2-years writing	Meretsky et al. (2006)
Oil Sands Monitoring	Hatfield Consultants	1-week meeting 1-month writing	Hughes and Whittier (2008)
Oregon Water Temperature Standard	Oregon Watershed Enhancement Board	2-day meeting 4-month writing	IMST (2004)
Pebble Dam	Wild Salmon Center Trout Unlimited	1-day meeting 1-year writing	Chambers et al. (2012)
Rio Grande Silvery Minnow	Bureau of Reclamation	1-week meeting 6-month writing	Hubert et al. (2016)
SAB Review of Connectivity Report	USEPA	1-week meeting 6-month writing	SAB (2014)
Salmonid Conservation	National Marine Fisheries Service	3-day meeting 2-year writing	Spence et al. (1996)

steps and more time to the review process, such a review is a crucial advance to make the process more in line with the NEPA. More importantly, rushing a decision is far more damaging than taking additional time to improve the probability of getting it right. In other words, peer review follows the United Nation's emphasis on the precautionary principle in making substantive decisions about the environment (EEA, 2001; Kriebel et al., 2001; DellaSala et al., 2022).

6. Conclusions

The expansive consumption of natural resources and even the transition to renewable energy economies will necessitate new mines, water storage and distribution developments, intensified forest management, and energy projects globally, all of which will have substantial and cumulative impacts. To move towards this future in a just and sustainable way, countries need to carefully assess the social, economic, physical, chemical, and biological risks (e.g., USEPA, 2014) using ISPR and assess accountability in response to ISPR. We conclude that the current EIS process nationally and globally is fundamentally flawed because it lacks accountability. Requiring ISPR would improve EIS credibility as well as both ecological health and economic outcomes. The CEQ and comparable agencies in other nations (Eccleston, 2008) must make these necessary and fundamental changes to the EIS process before embarking on another set of risky projects and management programs.

Correcting the flawed EIS process is a political problem—not a scientific one. Therefore, we urge that the CEQ, similar organizations in other nations, international agencies such as the World Bank and International Seabed Authority, professional societies, and the National Academy of Sciences convene formal review panels regarding how best to increase the role of ISPR in the EIS process. Those reviews should include a thorough, public review of prior EISs, including what went wrong with them and what succeeded, both ecologically and socioeconomically. The EIS processes must be overhauled to incorporate ISPR via conflict-of-interest waivers signed by scientists to assure no connection to project or agency funding sources. It does not serve decision makers or the public well if the results of EISs are misleading, wasteful of time and money, cannot be trusted, and are based on picking sides in scientific disputes in favor of desired outcomes (Lessing and Smosna, 1975; Peterson, 1993; Fairweather, 1994; Ortolano and Shepherd, 1995; Thompson et al., 1997). This is especially true given the current global climate and biodiversity crises (Gannon, 2021; Ripple et al., 2023). Peer review is the basis of all types of good science; thus, peer review should not be circumvented if we are to ensure effective environmental management and the protection of public safety.

CRediT authorship contribution statement

Robert M. Hughes: Writing – review & editing, Writing – original draft, Conceptualization. **David M. Chambers:** Writing – review & editing, Writing – original draft, Conceptualization. **Dominick A. DellaSala:** Writing – review & editing. **James R. Karr:** Writing – review & editing, Writing – original draft. **Susan C. Lubetkin:** Writing – review & editing, Writing – original draft. **Sarah O'Neal:** Writing – review & editing. **Robert L. Vadas:** Writing – review & editing. **Carol Ann Woody:** Writing – review & editing.

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As a Co-editor-in-Chief of *Water Biology & Security*, RMH examines the English and content of some manuscripts, but he was not involved in the manuscript editorial or peer reviews or the decision to publish this article. All authors declare no known competing financial interests or personal relationships that could potentially influence the work reported in this paper.

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