COMMENT

CHINA MINISTRY OF TRANSPORT/AP/REX/SHUTTERSTOCK

The *Sanchi* oil tanker on fire in the East China Sea after a collision with a cargo vessel in January 2018.

Human errors are behind most oil-tanker spills

Misleading accident data sets skew research and laws. **Zheng Wan** and **Jihong Chen** set out three priorities.

In January, the oil tanker *Sanchi* collided with a cargo vessel in the East China Sea, 300 kilometres off Shanghai, China. The tanker caught fire, exploded and sank, killing all 32 members of its crew and spilling or burning more than 100,000 tonnes of petroleum products. In May, China's Maritime Safety Administration gave its final verdict: both vessels had violated navigational protocols and watch-keeping codes[1]. Although accidents such as this are now rare, we fear that they could be set to increase.

Assuming much of its cargo entered the sea, *Sanchi* could be one of the largest such spills in nearly 30 years, since the *Exxon Valdez* dumped 37,000 tonnes of crude oil into Alaska's Prince William Sound in 1989. Even as the quantity of oil and gas transported by sea has doubled since the 1970s, there have been fewer spills greater than 7 tonnes — down from roughly 80 per year to about 7 per year (see 'Tanker trends'). Double hulls and fire-fighting systems that use inert gases have helped.

Two trends in the past decade threaten those improvements. First, the accident rate for major tankers (those that carry more than 15,000 tonnes, with and without spills) almost tripled between 2008 and 2017: from 1 accident for every 40 tankers to 1 in every 15 (ref. 2). Second, to cut costs, substandard ships with poor maintenance records and unqualified personnel are increasingly registered in countries that have lax regulation. The chance of a major spill occurring in a region that is unable to cope could rise, putting fragile coasts at risk.

Any spill is disastrous — ecologically, economically and socially. The *Exxon Valdez* disaster killed an estimated 250,000 seabirds, hundreds of otters, seals and eagles, and some two dozen killer whales. Oil vapours are toxic and contaminate seafood, harming public health and the local economy. And residues linger for decades[3]. Large spills, such as from the *Tasman Spirit*, which ran aground off Karachi in 2003, or from the *Prestige* that sank in 2002 off Galicia, Spain, cause billions of dollars in damages[4]. Clean-ups can cost more than US$20,000 per tonne of oil spilt[5].

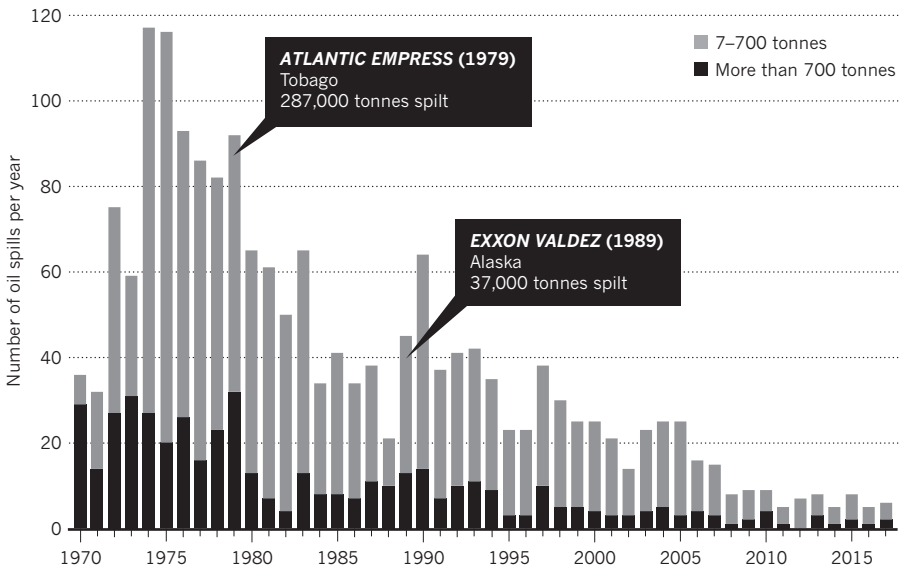
For the *Sanchi* spill, the ecological impacts, legal implications and clean-up strategies are unclear. The tanker was carrying 136,000 tonnes of condensate oil, a volatile and toxic hydrocarbon compound that is generated during the processing of natural ▶

TANKER TRENDS

The number of large oil spills from tankers has fallen since 1970. But increases in the volume of oil traded around the world and in accident rates could lead to more spills in the future.

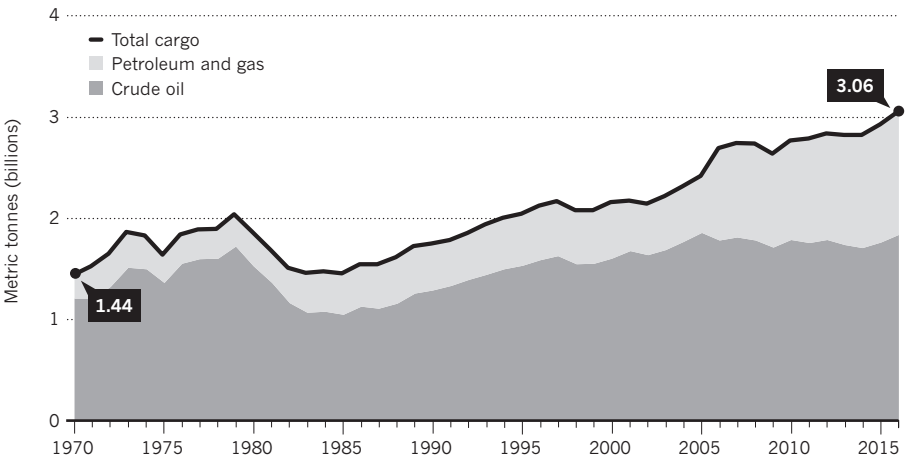
FEWER SPILLS

Double hulls and fire systems have reduced tank breaches.



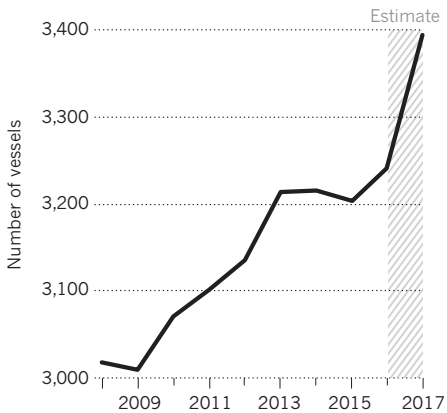
MORE CARGO

Rising energy use is increasing the volume of oil transported.



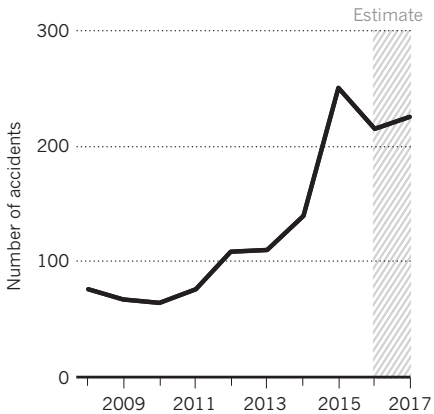
MORE SHIPS

A growing number of registered oil tankers have a carrying capacity of more than 15,000 tonnes.



MORE MISTAKES

Accidents are rising as trade grows and shipping lanes become congested.



SOURCES: 'FEWER SPILLS': ITOPF; 'MORE CARGO': UNCTAD; 'MORE SHIPS' & 'MORE MISTAKES': REF. 2

gas. Much of the unburnt cargo was spilt, together with 2,000 tonnes of the ship's own fuel. Ecological damage is inevitable. The area is a spawning ground for fish such as bluefin leatherjacket (*Thamnaconus septentrionalis*) and largehead hairtail (*Trichiurus japonicus*), and invertebrates such as swordtip squid (*Uroteuthis edulis*). It lies on a migratory route for at least three species of whale (see go.nature.com/2msmwn9). But no nation is duty-bound to issue an ecological assessment, because the accident happened in the high seas, beyond local jurisdictions. Neighbouring nations such as Japan and South Korea are keeping an eye on the situation. The tanker was Iranian-owned and registered in Panama. The cargo ship was based in Hong Kong.

Reducing accidents is the obvious answer. But the causes are widely misunderstood. Shipping records often list consequences — collisions, groundings and explosions — rather than reasons, such as poor navigation, lack of maintenance, miscommunication and other human errors. Researchers studying these databases thus reach the wrong conclusions and propose inappropriate policies. Tighter regulations on how ships are built do nothing if they go unenforced.

Clean-up technologies also need to improve to minimize damages from spills. The oil and shipping industries still use decades-old techniques, such as mixing chemical dispersants with oil-contaminated seawater. The dispersants break up the slicks into droplets that should, in theory, be easier for microorganisms to break down. But reactions can make the combination toxic to species such as rotifers (zooplankton at the base of the marine food web)[6]. There have been few long-term environmental studies of the ecological impacts of dispersants.

Researchers need to refocus discussions about tanker safety on to the human behaviours that cause accidents and on to improving safety protocols. They need to re-evaluate the risk-prediction models that are used to judge how often to inspect ships. Clean-up technologies also need to be improved and commercialized.

MULTIPLE FACTORS

The world's 7,000 oil tankers comprise 14% of the total shipping fleet. Tankers accounted for three-quarters of oil spills larger than 200 tonnes between 1974 and 2010, or more than 60% of the 9.8 million tonnes of oil spilt during that time[7]. The remainder came from pipelines, exploration and production and refineries.

The blame stretches beyond just the shipping operators. Half of oil tankers are registered in nations that do little to oversee vessel safety and crew training. A dozen countries, notably Panama, Liberia, the Marshall Islands, the Bahamas and Malta, allow almost any ship to fly their 'flags of convenience'. Panama and Liberia — the

nations with the biggest fleets — control 18% and 12% of the world's shipping tonnage (8,000 and 3,000 ships, respectively). Between 1967 and 2017, 12 of the tankers involved in the top 20 spills flew a convenient flag; 9 of those were from Liberia.

Tighter regulations are set out in the 1986 United Nations Convention on Conditions for Registration of Ships. It has yet to enter into force owing to industry lobbying. At least 40 states with more than 25% of the world's shipping tonnage must sign on; only 14 have done so.

In the meantime, coastal nations inspect foreign-registered vessels that enter their ports to ensure they comply with international maritime conventions. Port authorities use predictive models of risks to decide which vessels to inspect and how often. For example, a 20-year-old ship carrying dangerous cargo with poor safety records might be checked every 6 months; a new ship with good safety records every 36 months. But parameters such as ship age or historical safety records are unreliable indicators of risk. Older vessels are often safer — they have survived owing to better-quality or well-maintained equipment[8]. And historical safety records can be subjective and misleading. The results are shaped by who inspected the ship and how.

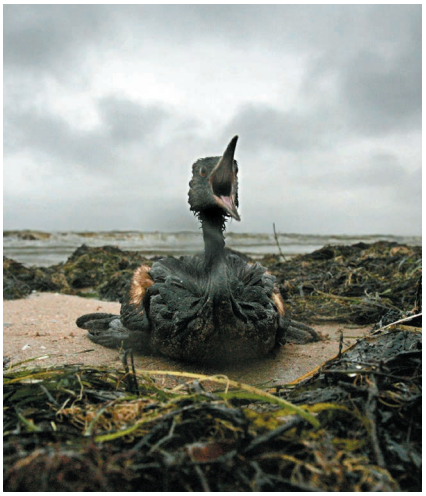
Checks are no deterrent[9]. Tighter inspections with heavier penalties in tightly regulated countries merely shift shabby ships to less-regulated nations. There are few civil or criminal penalties for flouting rules. Ships can travel thousands of kilometres between checks.

Port inspections are costly, for both authorities with limited staff and shipping companies with tight operating schedules. The scope is limited. It is easier to check the completeness of documents, such as records of crew rest hours, than the integrity of information. Flawless records can indicate that the crew is aware of the safety standards, or that they know how to fool the system.

ACKNOWLEDGE CAUSES

Human errors are behind at least 80% of tanker accidents (see go.nature.com/2nwgubp). Such errors include fatigue caused by overwork, inadequate expertise on a specific operation, poor communication or the use of outdated navigational charts. Yet these are rarely listed as causes in databases of shipping accidents[10]. Such confusion thwarts research and risk management.

For example, in 1994, the *Nassia* tanker spilt around 13,500 tonnes of crude oil in Turkey's Bosporus waterway. Records report that the tanker collided with another vessel, grounded and exploded. But other factors were not noted. For instance, the other vessel lost power and was unable to steer away from *Nassia*. The reason has not been established in this case, but inadequate maintenance and repairs are often a cause of engine problems (go.nature.com/2nymjsv).



SERGEI GRITS/AP/REX/SHUTTERSTOCK

Oil spills threaten seabirds and other marine life.

Researchers often misinterpret the statistical results generated by oversimplified and improper classification data sets. Collisions, groundings and explosions, for example, are described as primary causes for tanker incidents even though they are consequences (see go.nature.com/2jaekte). There is little or no information about the crew and their employer. Routinely calling to limit these physical factors without understanding the real drivers creates an unrealistic sense of hope in the shipping community that advancing technologies can solve all the problems. Weak policy prescriptions follow, such as mandating that ships are resistant to grounding.

Policies would be more effective if they acknowledged the role of human error. For example, crew fatigue caused by long working hours and isolation is a significant contributor. Raising the minimum number of qualified crew can reduce average workload and help to prevent mistakes.

THREE PRIORITIES

Research on the following would limit risk and damage.

Improve port inspections. Researchers should re-evaluate the algorithms that are used to decide which ships are inspected and when. The local maritime authorities should conduct randomized and controlled trials to optimize inspection strategies. They can borrow experiences from predictive policing schemes that use machine learning in some cities to fight crime[11]. Developed nations should provide aid for developing nations to ensure uniform standards.

Inspectors should look beyond records and, for example, conduct random interviews with crew members to judge whether they understand the safety protocols. We recommend they include surprise questions to test how tanker crew members will react in a crisis.

Study human errors. The International Maritime Organization (IMO) should collaborate with the research community to better understand how human error contributes to shipping accidents. Accurate data sets that document the objective causes of the incidents are key. Researchers need to revisit previous oil-spill incidents and reclassify the causes. Types of human error can be identified through the investigation reports on the IMO's website.

The tanker industry must use these data to design better strategies for reducing human errors. For example, language is a barrier for many multicultural crews and could be improved through training.

Develop sustainable clean-up technologies. New physical and mechanical clean-up methods should be developed. Promising methods are emerging, such as soak-up sponges, bioremediation and devices for separating oil and water. They still need to be commercialized. Chemists and toxicologists should evaluate chemical dispersants for efficacy and toxicity. Government agencies and the oil industry should prioritize the funding of such interdisciplinary research.

As our understanding improves, regulatory instruments must also evolve. States need to take responsibility for their fleets. For example, only vessels owned by capital invested by a certain country or that sail in its waters for a considerable time should be entitled to that nation's flag. Countries would thus have more incentive and be more able to exercise jurisdiction and control. The IMO should require that the tanker industry signs up to this reformed registration system first. As global energy demands grow, tanker safety must remain a priority. ■

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