Australasian Transport Research Forum 2023 Proceedings
29 November – 1 December, Perth, Australia
Publication website: http://www.atrf.info

Potentials for circular economy in marine transport: Early findings in sustainable disposal of derelict recreational vessels

Fahimeh Golbabaei[1], Alexander Paz[1], Jonathan Bunker[1]

[1]School of Civil and Environmental Engineering, Queensland University of Technology, 2 George Street, Brisbane, QLD 4000, Australia

Email: fahimeh.golbabaei@hdr.qut.edu.au; alexander.paz@qut.edu.au; j.bunker@qut.edu.au

Email for correspondence: fahimeh.golbabaei@hdr.qut.edu.au

Abstract

Current management practices for derelict vessels, or end-of-life vessels (ELVs), are inefficient. The recycling of recreational vessels is rare, which is a missed opportunity for promoting a circular economy. Numerous ELVs are left abandoned, illegally dumped in landfills, or sunk, causing environmental damage, health risks, and navigation hazards. Marina and municipal authorities face additional costs in handling abandoned vessels.

The industry, research, and policy sectors have increasingly focused on the possibility of making vessel owners or manufacturers financially accountable for managing ELVs. Wooden and steel vessels can easily be recycled through scrap yards, unlike Fiber Reinforced Polymer/Plastic (FRP) or composite (fibreglass) vessels.

This bridged paper aims to present preliminary findings of the project entitled “sustainable disposal of derelict vessels” which aims to synthesize current practices and future policies and practices for sustainable vessel disposal.

In the desire to consider sustainable disposal of vessels, it is useful to consider not only the final-stage removal to landfill but also to support more sustainable options such as reuse and recycling of vessel materials, as well as encouraging vessel producers and vessel users to consider environmentally sensitive options across the full vessel life cycle.

As such methods are considered, the study should also consider metrics of performance, including but not limited to cost-effectiveness, that will support policymaking in this space. This bridged paper will present the project scope and key findings of the literature review.

Keywords: circular economy; sustainable disposal; derelict recreational vessels

1. Introduction

Recreational vessels, primarily made from durable Fibre Reinforced Plastic/Polymer (FRP) materials since the 1950s, have gained popularity as family weekend activities. The COVID-19 pandemic saw an increase in fibreglass vessel purchases, raising concerns about their disposal and climate change's impact on distribution. Current disposal methods, such as landfilling, sinking, or abandonment, are neither sustainable nor economically viable due to hazardous chemical leaching.

The main challenge lies in finding safe, managed, and sustainable disposal options for the composite plastics present in end-of-life vessels (ELVs) that have accumulated over the past 50 years (Stoter, 2017; Dejhala & Legović, 2018).

The disposal problem related to end-of-life vessels can be viewed from two standpoints:

1) abandoned vessels, which are vessels that have been left without proper care and ownership is difficult to trace, and

2) future ELVs, which are vessels that will eventually reach their end-of-life and require a responsible and environmentally friendly disposal method. Addressing both aspects is essential for managing the growing issue of abandoned and derelict vessels (ADVs).

There is a general agreement among experts that research trends align with the reality concerning environmental sustainability, the circular economy, and the strategy established by Agenda 2030 (Martínez-Vázquez, 2022). The effectiveness of the recycling method depends on the materials used during the vessel's manufacturing. In some cases, complete recycling might be feasible, while in others, challenges may arise concerning material utilization.

Nevertheless, the most significant point is the necessity to enhance the scrapping process for recreational vessels. By doing so, materials and waste products can be managed more safely and efficiently within the framework of the circular economy.

The circular economy revolves around fundamental principles: preserving and enhancing natural capital, maximizing resource yields, and fostering eco-efficiency within systems. Kirchherr (2017) offers an extensive exploration of the circular economy concept, increasingly depicting it as an amalgamation of reduction, reuse, and recycling activities, with limited direct connections to sustainable development.

2. Research scope

The recent “War on Wrecks” task force provided by Maritime Safety Queensland (MSQ) had several important recommendations to improve the long-term sustainability of vessel purchase, use, and disposal, including (MSQ, 2019):

- Improvement of access to vessel disposal facilities. With its extensive coastline, there are many locations where vessel registrations and use are high, but these are often quite distant from facilities for vessel waste and recycling. Vessels must be lifted from the water and may need to travel significant distances to these facilities. Reducing the cost of lifting and transport, and improving the availability of these facilities and disposal sites, may be explored.
- Recycling/reuse targets. It is possible that specific programs and targets may be proposed to encourage producers to change input materials, or to encourage vessel owners to recycle or reuse vessel components. This would have the effect of reducing the amount of material reaching landfill, and encouraging more sustainable management of vessel materials. Fibreglass recycling programs, reduction of fibreglass material components in vessels, reduced use of resins, or other practices could be investigated.
- Support for recycling and eco-friendly disposal. One may imagine programs where vessel owners may receive some financial support for recycling the vessels or at least consider more environmentally friendly means of disposal. Scrapping bonuses or related financial incentives could be considered to encourage more responsible vessel disposal. Particularly in the case of fibreglass vessels, there is currently limited value in recycling fibreglass

materials; it may be that greater incentives or more valuable methods of product disposal can be investigated.
- Extended producer responsibility. The intent of these programs is to consider how the producer of certain products may take greater responsibility for the end-of-life processing of the product. There is a need for more research on how these types of programs may be relevant to the boating industry.

While the "War on Wrecks" has made significant progress, it is worth considering what methods might be most effective in operationalising these recommendations. In light of the many recommendations, one might consider the costs of different policies, the effectiveness of those policies in identifying and removing derelict ships from the current stock of vessels, and the potential environmental benefits from the reuse, recycling, or direct disposal of these vessels. This project seeks to better identify and quantify the impacts of these policies.

3. Findings

Transport for NSW recently shared key conclusions from a study examining the issue of end-of-life vessels (ELVs). The findings highlight the following causes of the problem (NSW Government, 2023):

- The ELV issue is complex and worsens as a vessel ages.
- Early life cycle factors involve manufacturers, their use of fibreglass, and lack of responsibility for disposal after the initial sale.
- Mid-life cycle factors mainly relate to vessel owners, who often do not contribute to disposal and may shorten a vessel's usable life through mismanagement.
- The vessel's owner is solely responsible for removing an ELV at the end of its life, which can be costly and difficult, with limited disposal options available.

The literature review reveals that the small scale of the ELV recycling market is due to unfavourable economic factors, such as high dismantling and disposal costs and limited revenue potential. This high-cost, low-return environment deters operators from offering facilities and vessel owners from pursuing proper disposal methods. The absence of vessel owner registration systems makes it challenging to effectively monitor and enforce ELV regulations, hindering efficient control management. Although financially viable options are scarce, the market is evolving, with crushed FRP material being utilized in concrete, tarmac, and as filler for other FRP products.

The market has good intentions, but its cost model has limited applicability and is particularly marginal due to insufficient recycling infrastructure. If this model is implemented, significant transport costs for FRP material are likely to be incurred.

Research and trials are exploring options such as pyrolysis (Mohee et al, 2015), where the material is burned at high temperatures to recover fibres for reuse (although resins are lost during combustion), and solvolysis (Oliveux et al., 2015a,b; Vladimirov & Bica, 2017), which involves chemical replacement to release resins and fibres for reuse. While these processes are currently expensive and not fully commercially viable, researchers and commercial groups are working towards financial feasibility.

To achieve financial sustainability for fibreglass ELV disposal, measures like levies on vessel ownership and production, as well as robust owner registration systems involving introducing an Eco Tax on all newly registered vessels could be beneficial, as seen in France through the Association for Pleasure Eco-Responsible Craft (APER) that is a non profit organization, created in 2009 by the French Nautical Industries Federation (Barbleu, 2014, APER, 2023).

Vessel insurers could also add a similar levy to annual premiums, which can be accumulated and paid to boat breakers when the vessel reaches its end-of-life.

The environmental impacts of current disposal options are also discussed. Burning, previously practised in some UK states (International Maritime Organization, 2019), is known to release highly toxic compounds with potential effects on biological organisms. Landfill options primarily relate to the amount of space occupied, which poses a significant issue. While the chemical breakdown and risk of FRP in landfills have been considered, degradation is deemed unlikely, with FRP material showing little change over time.

The effects of at-sea disposal are less well understood, but it is clear that dumped FRP vessels do not make suitable artificial reefs, as they tend to break up and can be moved by currents and waves, potentially damaging sensitive features (e.g., reefs, seagrass) and communities (International Maritime Organization, 2019). Consequently, FRP vessels are often left to decay on abandoned moorings. The International Convention for the Prevention of Pollution from Ships (MARPOL) prohibits discharging plastic at sea, but FRP hulls are not covered since MARPOL applies to shipborne garbage (Australian Maritime Safety Authority (AMSA), 2023).

The literature examined has led to exploring alternative construction materials for boat hulls as a potential future option. These alternatives have been gaining recent attention, but there are still issues to resolve regarding mechanical strength and scale to make them economical. In regions with limited space, long-term solutions that significantly reduce waste and offer alternative approaches to practical problems may benefit from considering more biodegradable or easily disposable boat hull materials (Compton, 2021; Plasti Fab, 2022; Greenboats, 2023).

The composite upcycling initiative with the Italian Marine Association is progressing steadily, even amid pandemic-related obstacles. The approach involves encapsulating the entire granular material, without separating the resin and glass fibre, in a novel 'micro envelope' that should preferably not be another thermosetting substance. Transforming it into a thermoplastic matrix ensures that the repurposed material doesn't face the same recycling challenges when it reaches the end of its life. Ideally, other components in the matrix should be sourced from another high-volume waste stream, like expanded polystyrene packaging.

This mix enables the integration of thermosetting granules (from decommissioned vessels, wind turbine blades, and so on) into a uniform matrix, resulting in a thermoplastic sheet material. This versatile material can then be utilized in various applications, such as furniture, lighting fixtures, flooring, and countertops (Korec, 2019; Franklin, 2021; Loiber, 2021).

Separating materials from disassembled vessels is not very practical due to the presence of sealants, adhesives, and various sandwich constructions, making it a time-consuming and uneconomical task. In the United States (Washington Department of Natural Resources, 2002, 2014, 2015), Scandinavia (Eklund, 2013; Evak, 2017), Italy (Baradel et al., 2012), and the Netherlands (Van der Pijll, 2022), several upcycling techniques have been effectively experimented with and implemented to transform fibreglass waste into valuable, reusable materials (Ecofiber Recycling AS., 2023; Eco Wolf Inc., 2023).

Another pioneering initiative has surfaced on the east coast of the US, where the Rhode Island Marine Trades Association has adeptly managed to discard 18 tons of decommissioned vessels through cement kiln co-processing. This approach reintegrates glass-reinforced polymer (GRP) waste into a widely-used construction material, rather than disposing of it in landfills (Ridley, 2020, Rhode Island Marine Trades Association, 2018).

4. Concluding remarks

The small size of the end-of-life boat (ELB) recycling and dismantling market indicates unfavourable economic opportunities for the industry. Obstacles to potential future management alternatives and the detrimental consequences of fibre-reinforced plastic (FRP) vessel disposal (legally or illegally) are anticipated to grow globally. Although no single policy option can fully address all ELB-related issues, a combination of policy strategiess, such as owner registration, research funding, and a managed fund, are proposed to represent varying degrees of management (Figure 1).

While these insights stem from international best practices, the main conclusions are generally applicable to a global challenge, with some degree of variation. Nonetheless, it is crucial to recognize that a one-size-fits-all solution does not exist for this issue, and specific local circumstances are likely to require customized approaches.

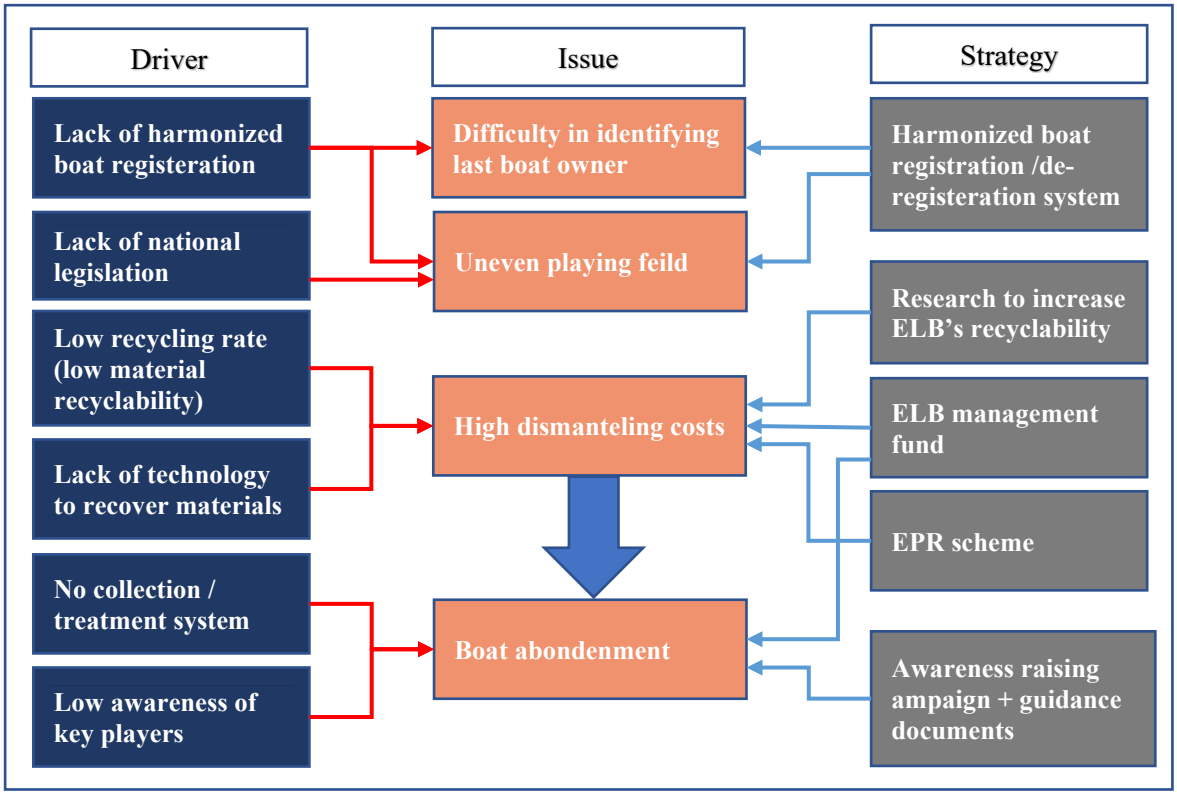

Figure 1. Conceptual framework of the drivers, issues, and strategies for ELB management

Examining successful stories, it becomes evident that in each instance, financial support was provided, and boat owners were relieved of the associated costs. By integrating further technological innovation and strategic thinking, this approach undoubtedly presents a solution for a persistent issue that must be addressed effectively.

Marine waste highlights the need for circular economy-based initiatives to promote recycling and material retrieval in the maritime sector, including ship dismantling. The circular economy, life cycle management, and sustainability are essential for examining vessel manufacturing processes and reducing environmental impacts and CO2 emissions.

Although current advancements may be limited, ongoing research into sustainable alternatives is being pursued due to the rising interest and financial or policy incentives. The primary

objective is to achieve end-of-life management that leads to either reuse (re-purposing) or recycling. These goals necessitate focused efforts to prevent increasing conflicts with natural resources and unregulated disposal of FRP waste, which could have environmental repercussions. In alignment with Cusato (2022), a comprehensive, sustainable, and robust solution to the abandoned and derelict vessel (ADV) issue involves legislative and policy changes, as well as dedicated funding (with a non-reverting fund exclusively supporting the ADV program).

The ADV prevention and removal plan will necessitate staff to document vessel locations, track ownership, prioritize removal and disposal, and manage contracts for ADV removal and disposal. Additional resources will be required to educate vessel owners about their responsibilities for disposing of older vessels, identify at-risk vessels, investigate options for fibreglass hull reuses, and potentially establish a vessel turn-in (VTIP) program (Washington Department of Natural Resources, 2014; Flood & Register, 2022). Implementing a buy-back or turn-in scheme for vessels can help place a value on them while addressing issues related to old, unused, or abandoned vessels.

A successful vessel buy-back or turn-in program would require the collaboration of various stakeholders, including vessel owners, government agencies, recycling facilities, and other organizations. Here is a step-by-step guide on how to implement such a scheme:

- Establish goals: Clearly define the objectives of the program, such as reducing abandoned vessels, encouraging vessel owners to upgrade to more environmentally friendly models, or promoting safe boating practices.
- Develop guidelines: Create a comprehensive set of guidelines for determining the eligibility of vessels for the buy-back or turn-in program. These guidelines should include factors such as vessel age, type, condition, and ownership status.
- Determine the value: Develop a valuation system to calculate the buy-back or turn-in value for eligible vessels. This system could be based on factors such as vessel age, condition, market value, or a combination of these. It's essential to offer a fair and attractive price to encourage vessel owners to participate in the program.
- Funding: Secure funding for the program through government grants, sponsorships, or public-private partnerships. The funding should cover the costs of buying back vessels, disposing of or recycling them, and administrative expenses.
- Partner with recycling facilities: Establish partnerships with local recycling facilities or vessel dismantling centres to ensure proper disposal of the vessels that are turned in.
- Outreach and promotion: Create a marketing and outreach campaign to raise awareness about the program among vessel owners and the general public. Provide information on the benefits of participating in the program and the process for turning in a vessel.
- Implement the program: Set up the infrastructure for processing vessel turn-ins, including creating a user-friendly online portal or physical locations for vessel owners to submit their vessels for the program. Ensure efficient processing and payment to vessel owners.
- Monitor and evaluate: Continuously monitor the program's performance and its impact on the goals established at the outset. Make necessary adjustments and improvements to ensure the program's success and sustainability.
- Reporting: Regularly report the program's progress and outcomes to relevant stakeholders and the public to maintain transparency and foster trust in the program.

By implementing a buy-back or turn-in scheme for vessels, vessel owners would be encouraged to dispose of their old or unwanted vessels responsibly, reduce the number of vessels that eventually become ADVs, save both vessel owners and the Commonwealth money and promote environmental sustainability, and support the circular economy.

5. References

APER. Association for Pleasure Eco-Responsible Craft (2023). *The recreational boat dismantling industry.* https://www.recyclermonbateau.fr/

Australian Maritime Safety Authority. (2023). MARPOL and its implementation in Australia. https://www.amsa.gov.au/marine-environment/marine-pollution/marpol-and-its-implementation-australia

Baradel, A., Fromentoux, M., Manceau, S. (2012). *Projet d'étude: les bateaux de plaisance en fin de vie.* EME, ECONAV. https://www.hisse-et-oh.com/store/medias/tavern/5db/8c4/e03/original/5db8c4e039819f5e986fe3f9.pdf

Barbleu, P. (2014). *Network of dismantling recreational craft in France.* Association pour la Plaisance Eco-Responsable. https://www.europeanboatingindustry.eu/images/News/boot2014_APER.pdf

Compton, N. (2021). *What's the future for derelict GRP boats?* Yachting Monthly. https://www.yachtingmonthly.com/gear/whats-the-future-for-derelict-grp-boats-77639

Cusato, A. (2022). *Abandoned and Derelict Vessels in the Commonwealth: How to Improve Virginia's ADV Program.* Virginia Coastal Policy Center (VCPC), College of William & Mary's. https://law.wm.edu/academics/programs/jd/electives/clinics/practicum_list/vacoastal/reports/adv-draft-2022may10.pdf

Dejhala, R., & Legović, D. (2018). *Disposal of worn out fiberglass recreational boats*. Journal of Maritime and Transportation Sciences, Special ed. (2), 143-153. https://www.researchgate.net/publication/331025835_Disposal_of_Worn_Out_Fiberglass_Recreational_Boats

Eco Wolf Inc. (2023). *All made with recycled FRP.* http://www.ecowolfinc.com/

Ecofiber Recycling AS. (2023). https://www.ecofiber.no/

Evak. (2017). *Virtual project of a ship purchased, dismantled and recycled at Turku Repair Yard.* Ship Recycling in Finland. http://evak.fi/wp-content/uploads/2021/02/Ship_recycling_in_Finland_Final_Report.pdf

Flood, J., and Register, K. (2022). *Report from the Virginia Abandoned and Derelict Vessels Work Group. Prepared for the Virginia Coastal Zone Management Program.* Virginia Coastal Zone Management Program. https://www.longwood.edu/cleanva/images/REPORT%20VA%20ADV%20Work%20Group%20FULL%20July%202022.pdf

Franklin, P. (2021). *The DISPOSAL OF END-OF-USE BOATS - SUSTAINABILITY PANEL REVIEW.* Metstrade. https://www.metstrade.com/news/sustainability/end-of-use-boats-disposal-sustainability-panel-review/

Greenboats. (2023). https://green-boats.de/?lang=en

International Maritime Organization. (2019). *End-Of-Life Management of Fibre Reinforced Plastic Vessels: Alternatives To At Sea Disposal.* End-of-Life Management of Fibre Reinforced Plastic Vessels: Alternatives to At Sea Disposal

Kirchherr, J., (2017). *Conceptualizing the circular economy: an analysis of 114 definitions. Resour.* Conserv. Recycl. 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Korec. (2019). *Innovative process for recycling fibreglass waste.* http://www.ko-rec.com/

Loiber, D. (2021). *Fiberglass Disposal 2: Vanishing Acts.* Professional Boatbuilder. https://www.proboat.com/2021/03/fiberglass-disposal-2/

Maritime Safety Queensland (2019). *War on Wrecks Taskforce Interim Report.* https://www.msq.qld.gov.au/-media/TMROnline/msqinternet/MSQFiles/Home/WoW-Taskforce-Interim-Report-March-2019.pdf?la=en

Martinez-Vazquez, R.M. (2022). *Challenges and opportunities for the future of recreational boat scrapping - The Spanish case.* Faculty of Economics and Business, University of Almeria. https://www.sciencedirect.com/science/article/pii/S0025326X22002399

Mohee, R., Mauthoor, S., Bundhoo, Z. M. A., Somaroo, G., and Soobhany, N. (2015). *Current status of solid waste management in small island developing states: A review. Waste Management, 43*, 539–549. https://www.sciencedirect.com/science/article/abs/pii/S0956053X15004262

NSW Government. (2023). *Managing End of Life Vessels.* https://www.haveyoursay.nsw.gov.au/end-of-life-vessels

Oliveux, G., Dandy, L. O., and Leeke, G. A. (2015a). *Degradation of a model epoxy resin by solvolysis routes.* Polymer Degradation and Stability, 118, 96–103. http://doi.org/10.1016/j.polymdegradstab.2015.04.016

Oliveux, G., Dandy, L.O. and Leeke, G.A. (2015b). *Current status of recycling of fibre reinforced polymers: Review of technologies, reuse and resulting properties.* Progress in Materials Science, 72, 61-99. https://www.sciencedirect.com/science/article/pii/S0079642515000316

Plasti Fab. (2022). *Recycling Fibreglass – FRP Manufacturing.* https://www.plasti-fab.com/recycling-fiberglass-frp-manufacturing/

Rhode Island Marine Trades Association. (2018). *End-Of-Life Vessel Material Management Guide.* RIMTA. https://marinedebris.noaa.gov/sites/default/files/publications-files/RIMTA-End-of-Life-Vessel-Material-Management-Guide.pdf

Ridley, E. (2020). *Rhode Island Fiberglass Vessel Recycling (RIFVR) Pilot Project.* Rhode Island Marine Trades Association. https://rimta.org/wp-content/uploads/2020/06/RIFVR-Background-6-2020.pdf

Snohomish County Washington. (2023). *Junk Vehicle and Boat/RV Disposal Program.* https://snohomishcountywa.gov/546/Junk-VehicleBoatRV-Disposal

Stoter, J., (2017). *Reduction in the amount of dumped polyester end-of-life boats in Fiji* (Doctoral dissertation, Faculty of Science and Engineering). https://fse.studenttheses.ub.rug.nl/id/eprint/15135

Van der Pijll, B. (2022). *Bootdump Nederland BV.* - Bootdump Nederland BV

Vladimirov, V., and Bica, I. (2017). *Mechanical Recycling: Solutions for Glass Fibre Reinforced Composites.* International Symposium "The Environment and The

Industry", Simi 2017, Proceedings Book. Pollution Assessment and Management Systems, 159–165. http://doi.org/10.21698/simi.2017.0020

Washington Department of Natural Resources. (2002). *Derelict Vessel Removal Program (DVRP).* https://www.dnr.wa.gov/programs-and-services/aquatics/derelict-vessels/legal-authorities-and-how-program-works#moorage-facilities

Washington Department of Natural Resources. (2014). *Vessel Turn-In Program*. https://www.dnr.wa.gov/programs-and-services/aquatics/derelict-vessels/vessel-turn-program

Washington Department of Natural Resources. (2015). *Derelict Vessel Removal Program Guidelines*. https://www.slc.ca.gov/wp-content/uploads/2018/10/Abandoned-AbadonedProgram.pdf