



Aotearoa New Zealand Marine
Activity-Pressure Matrix:
Development report for the first
five activity groups

Prepared for Department of Conservation

May 2025

Prepared by:
Emily Douglas
Carolyn Lundquist

For any information regarding this report please contact:

Emily Douglas
Marine Ecologist

+64 7 856 1728
emily.douglas@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 11115
Hamilton 3251

Phone +64 7 856 7026

NIWA CLIENT REPORT No: 2025124HN
Report date: May 2025
NIWA Project: DOC25205

Revision	Description	Date
Version 0.1	Draft in preparation/in review	14 May 2025
Version 1.0	Final version sent to client	11 June 2025
Version 1.1	Amendments to sections xxx	

Quality Assurance Statement		
	Reviewed by:	Tom Brough
	Formatting checked by:	Carole Evans
	Approved for release by:	Michael Bruce

© All rights reserved. This publication may not be reproduced or copied in any form without the permission of the copyright owner(s). Such permission is only to be given in accordance with the terms of the client's contract with NIWA. This copyright extends to all forms of copying and any storage of material in any kind of information retrieval system.

Whilst NIWA has used all reasonable endeavours to ensure that the information contained in this document is accurate, NIWA does not give any express or implied warranty as to the completeness of the information contained herein, or that it will be suitable for any purpose(s) other than those specifically contemplated during the project or agreed by NIWA and the client.

Contents

- Executive summary 4**

- 1 Introduction 5**

- 2 Methodological approach and outcomes 6**
 - 2.1 Prioritisation of activities 6
 - 2.2 Expert workshop 7
 - 2.3 Literature review 7
 - 2.4 Matrix population and scoring 7

- 3 Next steps 10**

- 4 Acknowledgements 11**

- 5 References 12**

- Appendix A Description of Activities used in the Aotearoa New Zealand Activity-
Pressure Matrix 13**

- Appendix B Description of Pressures used in the Aotearoa New Zealand Activity-
Pressure Matrix 20**

- Appendix C Matrix evidence 26**

Tables

- Table 2-1: Colour coding of evidence types. 9

Figures

- Figure 2-1: Example of populated matrix from expert workshop. 7
- Figure 2-2: Populated activity pressure matrix. 8
- Figure 2-3: Evidence table. 8

Executive summary

The Department of Conservation (DOC) has initiated a multi-stage project to link human activities to marine pressures within a standardised Aotearoa New Zealand Activities-Pressure Matrix. DOC contracted NIWA to begin population of the matrix which describes the links, or relationships between human activities and their associated pressures. A total of 22 high priority activities were populated, representing five broad activity categories:

1. production of living resources,
2. extraction (and disposal) of non-living resources,
3. energy generation,
4. transport, and
5. other man-made structures.

An initial population of the matrix of pressures relevant to each activity was undertaken at an expert workshop, which was used to guide a literature review to provide evidence for each activity-pressure relationship. If evidence was incidentally found for activity-pressure relationships not identified during the expert workshop, these pressures were subsequently added to the matrix.

A confidence scoring system was created to evaluate evidence for each activity-pressure relationship. Scores were based on evidence on the relationship between the activity and pressure being available in:

1. New Zealand peer-reviewed publications,
2. New Zealand grey literature (council reports, consultant assessments of environmental effects etc.),
3. International published and grey literature,
4. expert opinion (including opinions from the expert workshop for this project), and
5. no evidence found of the pressure-activity relationship.

The Activity-Pressure matrix is presented as a companion file to the report [Activity Pressure Matrix.xlsx].

1 Introduction

The coastal marine environment is subject to ongoing and changing pressures from a variety of human activities (Halpern et al. 2007; MacDiarmid et al. 2011a; MacDiarmid et al. 2012), however the full variety of pressures associated with current and future human activities in the marine environment are poorly understood. It is necessary to understand the types of impacts (pressures) of different activities on marine ecosystems to manage ecosystems and mitigate biodiversity loss.

The Department of Conservation (DOC) has initiated a multi-stage project to link human activities to marine pressures within a standardised Aotearoa New Zealand Activities-Pressure Matrix. DOC contracted NIWA to begin population of the matrix, which describes the links, or relationships, between human activities and their associated pressures. A later stage of the project will link pressures to species, habitats, and ecosystems in a pressure-biodiversity matrix to identify which components of biological diversity are impacted by each pressure. Management actions will then be linked to different activities to identify how they can be managed to avoid, remedy or minimise impacts of activities on biodiversity.

An aligned project contracted from the Ministry for the Environment (MfE) to NIWA as part of the broader work programme of the central government Marine Protected Areas Science Advisory Group (consisting of DOC, MfE, and Fisheries New Zealand) will produce a series of layers providing spatially-explicit representations of stressor footprints derived from human activities (e.g., excess sedimentation, turbidity, nutrient levels, and the spread of non-indigenous species). There are strong synergies between the two projects, with this DOC-led project aiming to identify the broad relationships between human activities and the pressures they create on the marine environment, and the MfE-led project collating the spatially-explicit maps of stressor footprints.

Alongside Fisheries New Zealand (FNZ) and MfE, DOC have also developed a Key Ecological Areas (KEA) framework, describing nine criteria that can be used to identify areas of high conservation value. These criteria include: 1) Vulnerability, Fragility, Sensitivity or Slow Recovery; (2) Uniqueness / Rarity / Endemism; (3) Special Importance for Life History Stages; (4) Importance for Threatened / Declining Species and Habitats; (5) Biological Primary Productivity; (6) Biological Diversity; (7) Naturalness; (8) Ecological Function; and (9) Ecological Services (Freeman et al. 2017). In combination, the DOC-led and MfE-led projects contribute to populating the 'Naturalness' KEA criterion.

To inform the suite of marine pressures to be analysed, DOC reviewed Aotearoa New Zealand and international lists of marine activities and pressures, including those contained in the JNCC Pressures Activities Database (Robson et al. 2018), the MarHADs tool (MacDiarmid et al. 2011b), and assessments of anthropogenic threats to New Zealand marine habitats (Baird and Wood 2012; MacDiarmid et al. 2012). DOC's review resulted in a categorised list of 65 activities (grouped within 11 activity categories) and 35 pressures and their definitions (Appendices A & B).

The aim of this project was to initiate the population of an activity-pressure matrix describing the links, or relationships, between human activities and their associated pressures.

2 Methodological approach and outcomes

The Activity-Pressure Matrix is provided as a companion file to this report 'Activity Pressure Matrix.xlsx'. This file is divided into the following tabs:

- Workshop matrix – results of the expert opinion workshop;
- Info – definition of matrix display components;
- Matrix – fully populated Activity-Pressure Matrix;
- Evidence table – list of references providing evidence for each of the identified activity pressure relationships (also provided in Appendix C).

2.1 Prioritisation of activities

Activities for inclusion in the initial matrix development were decided prior to project commencement based on priorities and alignment with the MfE-led project producing spatially explicit representations of stressor footprints derived from human activities (Lundquist et al. 2025). Some activities in the original activities list provided by DOC represented different phases of the same activity (e.g., in the original list, construction, operation and maintenance, and decommissioning of marine hydrocarbon extraction were listed as separate activities). Where these activities had similar impacts, they were merged into a broader activity (e.g., marine hydrocarbon extraction). Merged activities in the final activities list included Renewable energy – offshore wind, Renewable energy – wave energy, Marine hydrocarbon extraction (construction, operation and maintenance, and decommissioning merged) and Submarine cables (pipeline laying, burial and protection, operations and maintenance, and decommissioning merged). Vessel moorings and vessel berths were also merged. This resulted in 14 of the original 65 activities being merged into 5 activities. The 'addition of water to the marine environment' was added as an additional activity to the list, resulting in the final Activity-Pressure Matrix including a total of 57 activities. Activity-pressure relationships for 'Gas storage operations (carbon capture & natural gas storage)' are absent from the matrix as this is an emerging activity; we found no information and could not provide expert opinion of potential pressures to the marine environment.

There were 22 prioritised activities that were populated during this project, under the following five activity categories:

- Production of living resources (5 activities).
- Extraction (and disposal) of non-living resources (6 activities).
- Energy generation (4 activities).
- Transport (4 activities).
- Other man-made structures (3 activities; a 4th activity 'Gas storage operations (carbon capture & natural gas storage)' was not populated here).

The remaining 6 activity categories (which collectively include 34 activities) will be the focus of additional work.

2.2 Expert workshop

A workshop was held on 21 January 2025 to determine whether each type of pressure was anticipated to be associated with each activity. Decisions were based on the expert opinion and knowledge of the workshop participants (NIWA: Carolyn Lundquist, Emily Douglas, Tom Brough; DOC: Shane Geange) (Figure 2-1). These initial relationships were used to inform the literature review. Blank cells indicate no known relationship, maybe indicates a possible relationship, and ‘y’ indicates an activity-pressure relationship exists.

Activity Category	Pressure Theme		Hydrological changes (inshore/local)						Pollution and other chemical changes							
	Activities	Pressures	Temperature changes - local	Salinity changes - local*	Water flow (e.g., tidal current) changes - local	Emergence regime changes - local	Oxygen changes	pH changes	Wave exposure changes - local	Non-synthetic compound contamination - Transition elements & organo-metals	Non-synthetic compound contamination - Hydrocarbon & PAH Contamination	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	De-oxygenation	Nutrient enrichment	Organic enrichment	Radionuclide contamination
4: Production of living resources	Aquaculture - shellfish			y	y	y	maybe	y	y			y	y	y	y	
	Aquaculture - macro-algae			y			y	y	y			y	y	y	y	
	Ocean fertilization						y	y		y			y	y	y	
	Translocations and transplanting			maybe	y	y	maybe	y					y	y	y	
5: Extraction (and disposal) of non-living resources	Extraction - sand and gravel (aggregates)			y	y			y		y	y					
	Extraction - minerals			y	y			y		y	maybe	maybe	y	y	y	
	Extraction - maintenance dredging			y	y			y		y	maybe	maybe				
	Salvage operations									y	y	y		y	y	y
	Extraction - water (abstraction)		y	y	y	y	y	y					y	y	y	

Figure 2-1: Example of populated matrix from expert workshop.

2.3 Literature review

Evidence of each identified activity-pressure relationship was gathered using google searches of key words, as well as collated publications and work known to the authors. Searches were conducted for each activity by firstly starting with broad search phrases, e.g., ‘environmental impacts of [activity]’, or more specific terms such as ‘effects of [activity] on [pressure]’. When needed, the words ‘in New Zealand’ were added to search terms to specifically target New Zealand literature. The reference sections of relevant publications were reviewed to identify further relevant evidence.

2.4 Matrix population and scoring

The matrix consists of a table enabling visual demonstration of the pressures caused by each activity and the evidence-based confidence in each relationship (Figure 2-2). The matrix can be read horizontally to observe the pressures caused by each activity, or vertically to identify which activities contribute to a pressure of interest. Matrix cells contain numbers linking to the ‘Evidence table’ which consists of a list of references that provide evidence of each activity-pressure relationship, and their ranking (Figure 2-3). References and evidence ranking are listed horizontally for each pressure, and a ‘Best’ evidence column indicates the highest evidence rank of those included (i.e., a mixture of

evidence types is common). Up to six references were included for each activity-pressure relationship, and for some only one or two were found.

Activity Category	Pressure Theme		Hydrological changes (inshore/local)						Pollution and other chemical changes						Physical		
	Activities	Pressures	Temperature changes - local	Salinity changes - local*	Water flow (e.g. tidal current) changes - local	Emergence regime changes - local	Oxygen changes	pH changes	Wave exposure changes - local	Non-synthetic compound contamination - Transition elements & organo-metals	Non-synthetic compound contamination - Hydrocarbon & PAH Contamination	Synthetic compound contamination (metals, pesticides, antibiotics, pharmaceuticals)	De-oxygenation	Nutrient enrichment	Organic enrichment	Radionuclide contamination	Physical loss (to land or freshwater habitat)
4: Production of living resources	Aquaculture - shellfish		34		36	37	38		40	41		43	44	45	46		47
	Aquaculture - macro-algae				63		71	72	73			76	77	78	79		80
	Ocean fertilization						104	105		107			110	111	112		
	Translocations and transplanting				134				138					143	144		145
5: Extraction (and disposal) of non-living resources	Extraction - sand and gravel (aggregates)				167	168			171	172	173	174	175	176	177		178
	Extraction - minerals				200	201			204	205	206	207	208	209	210		211
	Extraction - maintenance dredging				232	233	234		237	238	239	240		242			243
	Salvage operations									271	272	273				277	
	Extraction - water (abstraction)			297	298	299		301	302	304		306					
	Addition - water			330	331	332		334	335	337		339		341	342		
Renewable energy - offshore wind construction/operation/maintenance/			363		365			368	370	371	372						373

Figure 2-2: Populated activity pressure matrix. Excerpt from matrix showing colour-coded cells with reference numbers corresponding to evidence table.

Activity Group	Activity	Pressure	Matrix cell identifier	Best	Ref 1 Evidence type identifier	Ref 1	Ref 2 Evidence type identifier	Ref 2
4: Production of living re:	Aquaculture - fin-	Water flow (e.g., tidal current) changes	3	1	2	Ministry for Primary Industries	1	Plew DR. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Oxygen changes	5	1	2	Ministry for Primary Industries	2	Forrest, R., Keeley, J. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Wave exposure changes - local	7	1	2	Ministry for Primary Industries	1	Plew DR. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Non-synthetic compound contamination (inorganic)	8	1	2	Ministry for Primary Industries	2	Clement, D.M., Keeley, J. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Synthetic compound contamination (inorganic)	10	2	2	Ministry for Primary Industries	2	Clement, D.M., Keeley, J. 2011. Dep
4: Production of living re:	Aquaculture - fin-	De-oxygenation	11	1	2	Ministry for Primary Industries	1	Hale R, Depree C, B. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Nutrient enrichment	12	1	2	Ministry for Primary Industries	1	Hale R, Depree C, B. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Organic enrichment	13	1	2	Ministry for Primary Industries	2	Forrest, R., Keeley, J. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Physical change (to another seabed type)	16	1	2	Ministry for Primary Industries	1	Watson, S.J., Neil, H. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Temporary and/or reversible change of seabed	17	1	2	MacDiarmid, A., Beal, M. 2011. Dep	1	Watson, S.J., Neil, H. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Disturbance of the surface of the seabed	18	2	2	Ministry for Primary Industries	2	MacDiarmid, A., Beal, M. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Penetration and/or disturbance of the seabed	19	1	1	Watson, S.J., Neil, H. 2011. Dep		
4: Production of living re:	Aquaculture - fin-	Changes in suspended solids	20	1	2	Ministry for Primary Industries	3	Brooks, K.M., Mahn, G. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Siltation rate changes	21	1	2	Ministry for Primary Industries	1	Morrissey, D.J., Gibb, J. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Litter	22	2	2	Sustainable Business Unit	2	McClellan, R., Reid, J. 2011. Dep
4: Production of living re:	Aquaculture - fin-	Underwater noise changes	24	2	2	Ministry for Primary Industries	2	Clement DM. 2013. Dep
4: Production of living re:	Aquaculture - fin-	Introduction of light	25	2	2	Ministry for Primary Industries	2	Cornelissen C. 2013. Dep

Figure 2-3: Evidence table. Excerpt from reference information illustrating ranking of each evidence type. Best column indicates the best evidence type and corresponds to the colours in the table.

The evidence in the matrix was colour-coded according to the evidence type available to support each activity-pressure relationship, as outlined in Table 2-1. Activity-pressure relationships that were incidentally identified during the literature search but not identified during the expert workshop were subsequently added to the matrix. Where a relationship was identified during the initial expert workshop, but no additional evidence was found, evidence was scored as ‘expert opinion’.

Table 2-1: Colour coding of evidence types.

Identifier	Evidence type
1	New Zealand published literature
2	New Zealand grey literature (council reports, consultant assessments of environmental effects etc.)
3	International published and grey literature
4	Expert opinion. i.e., workshop identified the presence of the stressor type, but no evidence was found.
-	No known relationship

Some of the literature ranked 1 and 2 consisted of New Zealand studies (e.g., reviews of environmental effects) that drew on overseas literature or studies of the effects of activities in other countries (e.g., Hale et al. 2024). This type of evidence was scored as New Zealand literature but indicated with an asterisk (*) in the evidence table.

3 Next steps

This project gathered evidence, populated and formatted the matrix for 22 activities, with multiple pressure relationships identified for most activities. Population of the remaining sections of the matrix will likely require a similar amount of time pro rata, although this will vary by activity and the quantity of existing literature (i.e., some activities such as fishing are expected to have a greater amount of literature available).

4 Acknowledgements

We thank Shane Geange for his guidance on this project and contribution to the expert workshop. We also thank Tom Brough for his contribution to the expert workshop. Finally, we thank Carole Evans for editorial support, and Tom Brough and Michael Bruce for reviewing this report.

5 References

- Baird, S., Wood, B. (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report*, No. 89: 43.
- Freeman, D., Ford, R., Funnell, G., Geange, S., Sharp, B., Tellier, P. (2017) Key Ecological Areas for Marine Protected Area Planning in New Zealand. *Note defining Key Ecological Areas*. Interim Marine Protected Areas Science Advisory Group.
- Hale, R., Thompson, D., Brough, T., Kregting, L., Hayden, M., Parsons, D., Nodder, S.D., Beaumont, J., Anderson, O., Stevens, C. (2024) Environmental implications of future offshore renewable energy development in Aotearoa New Zealand. *Journal of the Royal Society of New Zealand*: 1-34. 10.1080/03036758.2024.2406829
- Halpern, B.S., Selkoe, K.A., Micheli, F., Kappel, C.V. (2007) Evaluating and Ranking the Vulnerability of Global Marine Ecosystems to Anthropogenic Threats. *Conservation Biology*, 21(5): 1301-1315. <https://doi.org/10.1111/j.1523-1739.2007.00752.x>
- Lundquist, C., Yogesh, N., Leunissen, E., Douglas, E., Hoang, L., Stewart-Sinclair, P., Bennion M., Brough T. (2025) Spatial information to assess naturalness of marine habitats. *NIWA Client Report*, MFE24208: 122.
- MacDiarmid, A., Beaumont, J., Bostock, H., Bowden, D., Clark, M., Hadfield, M., Heath, P., Lamarche, G., Nodder, S., Orpin, A., Stevens, C., Thompson, D., Torres, L., Wysoczansk, R. (2011a) Expert Risk Assessment of Activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf. *NIWA Client Report*, WLG2011-39: 140. <https://environment.govt.nz/assets/publications/Files/niwa-risk-assessment-2012.pdf>
- MacDiarmid, A., McKenzie, A., Sturman, J., Beaumont, J., Mikaloff-Fletcher, S., Dunne, J. (2012) Assessment of anthropogenic threats to New Zealand marine habitats. *New Zealand Aquatic Environment and Biodiversity Report*, No. 93: 255.
- MacDiarmid, A., Taylor, P., Carbines, M., Hewitt, J., Bolton-Ritchie, L., Maharadz-Smith, A., Townsend, M., Thrush, S., Walker, J. (2011b) Marine Habitat Assessment Decision Support (MarHADS) Tool: Background and Operating Instructions. *NIWA Client Report*, ELF09240: 25.
- Robson, L., Fincham, J., Peckett, F., Frost, N., Jackson, C., Carter, A., Matear, L. (2018) UK Marine Pressures-Activities Database "PAD": Methods Report. *JNCC Report*, No. 624.

Appendix A Description of Activities used in the Aotearoa New Zealand Activity-Pressure Matrix

An initial list of 65 activities was provided by DOC. Fourteen activities were merged into five broader activity categories (e.g., Submarine cables and pipelines – operations, maintenance and decommissioning instead of three individual categories), reflecting evidence that was difficult to differentiate between impacts during the life cycle of an activity. Merged activities are noted by shaded cells. This resulted in a total of 57 activities in the matrix.

Category Title	Activity Title	Activity Description
Coastal Management Activities	Coastal defence & land claim protection (incl. beach replenishment)	Development and maintenance of coastal defences including management of beaches, bunds, ditches/drainage, managed realignment sites, beach/sediment recharge or on-going sediment feeding, management of vegetation, sand dune stabilisation. Includes consideration of vessels/machinery/vehicles and materials associated with activity.
	Coastal boat ramps, docks, ports & marinas	Building, expanding, and upgrading coastal boat ramps, docks, berths, ports and marinas. This includes creating new facilities as well as improving existing structures. Includes consideration of vessels/machinery/ vehicles, and materials associated with activity e.g., jack-up barges, piling plant, dredgers, barges.
	Forestry	This activity considers (i) the effects of removing existing forests and (ii) afforestation (the planting of trees). Includes consideration of machinery/vehicles and materials associated with activity.
	Farming and Agriculture	This activity includes the use of coastal areas for grazing of domestic animals (e.g., cows, sheep and horses) and drainage and fertilisation of coastal areas to improve grazing and agriculture. Includes consideration of machinery/vehicles and materials associated with activity.
	Strandline clearance	Considers the removal the removal of natural debris, such as seaweed and driftwood, that accumulates along the high tide line on beaches. The process of clearing the strandline is often done to maintain the cleanliness and appearance of beaches, but it can also impact the local ecosystem, as the debris provides habitat and nutrients for various coastal species.
	Reclamations and causeways	This activity considers reclaiming land from below the high-water mark to create new areas for quaysides, coastal defences, or port estates. This often involves building new walls or hard defences and filling in behind them to raise the land level. It also considers the vessels, machinery, vehicles, and materials needed for these activities.
Waste management activities	Residential and urban wastewater (incl. storm water and aquarium) discharges	This considers the construction, maintenance, and ongoing use of outfall pipes. These pipes could discharge liquids at varying temperatures, salinities, oxygen, nutrient concentrations. Includes consideration of vessels/machinery/vehicles and materials associated with construction, maintenance operational usage of infrastructure.

Category Title	Activity Title	Activity Description
	Sewage disposal discharges	The release of wastewater, which includes sewage, from sewage treatment facilities. This wastewater can be treated or untreated.
	Industrial & agricultural liquid	The release of liquid waste products from industrial and agricultural activities into the marine environment. Discharges can contain chemical contaminants, organic matter and thermal pollution. These discharges can have significant environmental impacts if not properly managed.
	Waste disposal - munitions (chemical & conventional)	Sites where military ordnance has been discarded. These sites can pose environmental and safety risks due to the potential for chemical leaching and unexploded ordnance. Significant quantities of munitions were disposed of in the ocean around New Zealand after World War II, with continued disposal of obsolete or surplus munitions in subsequent years. Known sites include the Hauraki Gulf and Wellington harbour.
	Dredge & spoil disposal	The disposal of dredged materials originating from the bottom of water bodies, like rivers, lakes and harbours.
	Thermal effluent discharges	The discharge of heated water or steam into the environment, typically into rivers, lakes, or oceans, after being used in the cooling processes, for example in thermal power stations and geothermal power plants.
	Rocket abandonment	This activity refers to the practice of disposing of rocket stages and other space debris in the ocean after they have been used. This is often done to minimize the risk of debris causing damage on land.
Extraction of living resources	Fishing – bottom trawling	The use of large, weighted nets dragged along the sea floor to catch fish and other marine organisms. This technique targets species that live near or on the bottom of the ocean, such as hoki, orange roughy, and squid. Includes single otter trawl, twin otter trawl, beam trawl, and Danish seine.
	Fishing – dredging	The dragging a heavy frame with an attached net or metal mesh bag along the sea floor to collect shellfish and other benthic organisms. This technique is commonly used to harvest species like scallops, oysters, and clams.
	Fishing – midwater trawling	The towing of large net through the water column, to target species that live in the midwater zone, such as mackerel, hoki, and squid.
	Fishing – traps (potting/creeling)	This activity includes the use of pots, creels and traps, as well as fyke nets and other similar gear.
	Fishing – spear fishing	A method of fishing where individuals use a pole spear (Hawaiian sling) or speargun to catch fish. This technique is typically done while snorkelling or diving, and commonly targets snapper, kingfish and butterfish.

Category Title	Activity Title	Activity Description
	Fishing – set netting	The use of a net that is anchored or staked in place in the water to catch fish as they swim into it. This technique is commonly used in both coastal and freshwater environments to target a variety of fish species, including snapper, flounder and mullet. Non-target species, including protected species, can become entangled in set nets.
	Fishing - lines	The targeted removal of fish species using static hooks and lines that are left in place for a period before being recovered to retrieve the caught fish. Includes hand lines, rod and reel and longlines. Excludes beach seine.
	Fishing - seines (encircling), excluding beach seining	A method of fishing that uses a large net, called a seine, to encircle and capture schools of fish. This technique is commonly used in both coastal and open ocean environments.
	Fishing – beach seine	A seine net that is deployed from the shore and dragged back to the beach. Often used to target pilchards, mackerel and kahawai.
	Fishing - Diving and snorkelling	This activity involves the collection of target species by divers, snorkelers such as scallops, lobster and kina. Includes recreational diving but excludes spear fishing.
	Harvesting – seaweed and other sea-based food (e.g., paua, kina, mussels, pūpū etc.)	The collection of marine organisms by hand, excluding diving and snorkelling, without the use of nets, traps, lines or other fishing gear. This technique is often used for collecting shellfish, seaweed, and other easily accessible marine resources.
	Extraction of genetic resources e.g., bioprospecting (<i>blue technology</i>)	Bioprospecting involves collecting natural materials and developing new products from useful organic compounds found in biological resources. It also considers the vessels, machinery, vehicles, and materials needed for these activities.
Production of living resources	Aquaculture - finfish	This activity considers finfish grown in cages/nets suspended from surface structures or lines. These structures may be anchored to the seabed. It also considers the vessels, machinery, vehicles, and materials needed for these activities.
	Aquaculture - shellfish	This activity considers shellfish (mussels, oysters) grown on racks or trestles in the intertidal or grown on ropes/nets suspended from surface structures or lines. These structures may be anchored to the seabed. It also considers the vessels, machinery, vehicles, and materials needed for these activities.
	Aquaculture – macro-algae	This activity considers seaweed grown on ropes/nets suspended from surface structures or lines. These structures may be anchored to the seabed. It also considers the vessels, machinery, vehicles, and materials needed for these activities.
	Ocean fertilization	Adding nutrients (e.g., iron, nitrogen and/or phosphorous) to the ocean to stimulate the growth of phytoplankton and enhance marine productivity. It also considers the use of vessels to transport and

Category Title	Activity Title	Activity Description
		disperse nutrients over targeted areas, and wave pumps and floating tubes that bring nutrient-rich deep water to the surface.
	Translocations and transplanting	This activity considers transplanting or translocating marine organisms to bolster local populations. Examples include replanting seagrass in areas where it has been lost or seeding shellfish beds to enhance and restore local populations.
Extraction (and disposal) of non-living resources	Extraction – sand and gravel (aggregates)	This activity involves removing sand and gravel from the seabed using suction or grab dredgers for construction and beach replenishment. This activity is associated with numerous vessel movements, sediment alteration and resuspension.
	Extraction – minerals	This activity considers the extraction of minerals from the seabed such as polymetallic nodules and includes the use of seafloor mining devices, riser and lifting systems and mining support vessels.
	Extraction – maintenance dredging	This activity includes the periodic or regular removal of material from previously dredged areas (e.g., berths, channels, marinas). The method of dredging may vary, and material may be removed for disposal elsewhere or redistributed within the immediate area. Includes consideration of vessels/machinery/vehicles associated with activity.
	Salvage operations	Includes salvage of vessels or infrastructure, e.g., from oil and gas, wrecked on or near the coast. This activity considers the pressures associated with salvaging, including the removal of wrecked structures and pressures caused by supporting vessels.
	Extraction – water (abstraction)	The temporary or permanent removal of water from the marine environment. Addition of water (e.g., through freshwater diversion) to the marine environment.
	Addition - water	Addition of water (e.g., through freshwater diversion) to the marine environment
Energy generation	Renewable energy – offshore wind construction (not including cables)	This activity includes seabed preparation (possibly dredging), cuttings/dredging disposal, piling, drilling, anchoring, mooring, vessel movement, vessel discharges/emissions, installation of scour protection, introduction of artificial substrate. For cabling, please see and include the separate activity.
	Renewable energy – offshore wind operation and maintenance (not including cables)	Regular vessel movement, vessel discharges, rotor sweep, lighting, presence of turbine and foundation structures. Also includes use of jack up barges for maintenance and deposition of additional scour protection. For cabling, please see and include the separate activity.
	Renewable energy – offshore wind decommissioning (not including cables)	Vessel movement, vessel discharges, use of jack up barges, removal of structures/scour protection and associated habitat, use of explosives, cutting, drilling, excavation of seabed close to foundations. For cabling, please see and include the separate activity.

Category Title	Activity Title	Activity Description
	Renewable energy – wave energy construction (not including cables)	Seabed preparation (possibly dredging), cuttings/dredging disposal, mooring, anchoring, piling, drilling, vessel movement, vessel discharges/emissions, installation of scour protection, introduction of artificial substrate. For cabling, please see and include the separate activity.
	Renewable energy – wave energy operation and maintenance (not including cables)	Vessel movement, vessel discharges, lighting, operation of devices. For cabling, please see and include the separate activity.
	Renewable energy – wave energy decommissioning (not including cables)	Vessel movement, vessel discharges, removal of structures/cables and associated habitat, use of explosives, cutting, drilling. For cabling, please see and include the separate activity.
	Marine hydrocarbon extraction - exploration	This activity includes searching for oil and natural gas deposits beneath the ocean floor using controlled-source electromagnetic surveys and exploratory drilling. For seismic surveys, please see and include the separate activity.
	Marine hydrocarbon extraction - construction (not including pipelines)	This activity includes the construction of oil and gas infrastructure in the marine environment including, but not limited to, the installation of rock dump to stabilise jack up rigs, cementing, introduction of other protection material such as concrete mattresses, matting and gravel, the temporary installation of infrastructure (such as pipelines, debris baskets, etc), drilling wells and plugging and abandonment, accidental effects, vessel movement, installation of subsea infrastructure etc. For pipelines, please see and include the separate activity.
	Marine hydrocarbon extraction – operation and maintenance (not including pipelines)	Production/operation, with routine supply, return of wastes to shore, power generation, chemical use, produced water, and re-injection of reservoirs.
Transport	Marine hydrocarbon extraction - decommissioning (not including pipelines)	The plugging and abandonment of wells, removal of structures and associated habitat, use of explosives, cutting, drilling. Disturbance of drill arisings and cuttings. Placement of rock to cover remaining structures or to provide base for jack-up legs. Includes operation by supporting vessels, vessel discharges, use of ROVs, lifting and jack-up rigs. For pipelines, please see and include the separate activity.
	Shipping – port operations	Includes trans-shipment of cargo, loading and unloading of vessels, landside handling, logistics and onward transportation e.g., road, rail within port estate. Includes handling of hazardous cargo. Includes consideration of vessels/machinery/vehicles associated with activity.
	Vessel berths	Operational use of berths and the presence of these structures and vessels using them. Includes consideration of vessels when berthing/berthed.
	Vessel moorings	Use of vessel moorings and activity associated with mooring a vessel. Mooring is a temporary or permanent structure to which a vessel may be secured, e.g., swing mooring, trot, fore and aft mooring, pile mooring. Includes consideration of vessels when mooring or moored.

Category Title	Activity Title	Activity Description
	Anchoring	Covers activity of anchoring generically and use of allocated anchorage areas where vessels are permitted to anchor inside and outside harbours/ports. Including consideration of vessels when anchoring, anchored or weighing anchor
	Shipping – general (at sea)	Movement of all commercial or ‘non-recreation’ vessels of all scales, from container ships, tankers, cruise liners to pilot vessels, tugs and small watercraft, (including fishing vessels when not fishing). Includes operational, incidental and accidental discharges/emissions from all types of vessels, including noise pollution, exhaust fumes, wastes and wastewater, sewerage, oils, lubricants and chemicals, marine litter and other flotsam and jetsam.
Recreation & leisure	Coastal tourist sites (public beaches & resorts)	Includes activities where a vessel is not used. Includes swimming, surfing and event type activities (e.g., beach clean-ups, festivals).
	Ecotourism (whale watching, scuba diving etc)	Exploration and appreciation of marine environments while minimizing environmental impact and promoting conservation. Examples include snorkelling and diving, whale and dolphin watching, kayaking and paddle boarding, marine biology tours.
	Boating	Recreating on a boat. Encompasses a wide range of activities, including cruising, sailing, motorboating, kayaking and canoeing, and yachting.
	Vehicle use on the foreshore	Operation or parking of vehicles on the area of land that lies between the high and low tide marks along a coast. Vehicles can damage sensitive ecosystems, such as dunes and tidal flats, and disturb wildlife.
Marine research & exploration	Physical sampling	Physical sampling of the seabed, foreshore (intertidal) and/or water column in situ using a variety of marine survey techniques. It also considers the vessels, vehicles, and materials needed for these activities.
	Remote sensing	This includes methods of obtaining data or images from a distance, e.g., from satellites, AUV or aircraft and includes LIDAR. It also considers the vessels, vehicles, and materials needed for these activities.
	Seismic surveys	Any survey that uses airguns, including 2D/3D/4D and OBC (On Bottom Cabling) surveys and any similar techniques that use airguns. It also considers the vessels, vehicles, and materials needed for these activities.
	Sonar surveys	The use of echo sounders underwater for research or exploratory purposes as well as military purposes. It also considers the vessels, vehicles, and materials needed for these activities.

Category Title	Activity Title	Activity Description
Defence and national security	Military activities	Military exercises undertaken that involve the use of the sea surface (e.g., boats, surface explosions and surface target towing), water column (e.g. submarine use and diving) or seabed (e.g., installation and operation of seabed mounted equipment, seabed sampling and degaussing).
Other man-made structures	Submarine cable and pipeline laying, burial and protection	Includes the laying cables and pipelines. Methods vary depending on the water depth and include laying either directly on the seabed, covered with material for protection, or buried. Seabed trench excavation through ploughing and hydraulic jetting is frequently used for burial. Protection can also be added where there is a reasonable risk of damage by rock placement on the seabed over the cable or pipeline. It also considers the vessels, vehicles, machinery and materials needed for these activities.
	Submarine cable and pipeline operations and maintenance	This activity includes the retrieval or access of cables and pipelines for repairs or maintenance and their replacement following maintenance. The activity also includes vessel movement and anchoring during the operation.
	Submarine cable and pipeline decommissioning	Includes the removal or decommissioning of a cable or pipeline when it is no longer needed. When removal is deemed appropriate, cables and pipelines may be retrieved through grabbing and raising. The decommissioning process can include vessel movements and anchoring along the cable or pipeline route.
	Gas storage operations (carbon capture & natural gas storage)	This activity includes gas injection into submarine storage sites, often referred to as subsea gas storage. It includes injecting gases like carbon dioxide (CO ₂) or natural gas into geological formations beneath the seabed for both carbon capture and storage (CCS) and natural gas storage. It also considers the vessels, vehicles, machinery and materials needed for these activities.
	Artificial reefs and other environmental structures	Artificial reefs are human-made structures placed underwater to promote marine life. They can be made from a variety of materials, including concrete, steel, tires, natural materials (e.g., rocks, shells), specialized structures designed to mimic natural reef formations and sunken vessels. It also considers the vessels, vehicles, machinery and materials needed for the placement and maintenance of artificial reefs.
	Cultural & heritage sites/structures (e.g., wrecks, archaeological sites etc.)	Includes the presence of wrecks and archaeological sites.

Appendix B Description of Pressures used in the Aotearoa New Zealand Activity-Pressure Matrix

Category Title	Pressure Title	Pressure Description
Local hydrological changes (within a specific, often geographically limited, area)	Temperature changes - local	Events or activities that change local water temperature, like thermal discharges from power stations or temperature changes in the vicinity of subsea power cables, can affect the area around the source. This does not include regional temperature changes from global warming.
	Salinity changes - local	Events or activities increasing or decreasing local salinity. This includes freshwater discharges from pipelines that reduce salinity; hydro-morphological modification (e.g., navigational dredging) if this alters the halocline, or erection of barrages or weirs that alter freshwater/seawater flow/exchange rates.
	Water flow (e.g., tidal current) changes - local	Changes in water movement associated with tidal streams (the rise and fall of the tide, riverine flows), prevailing winds and ocean currents. The pressure is associated with activities that have the potential to modify hydrological energy flows. For example, tidal energy generation devices remove (convert) energy, and such pressures could be manifested leeward of the device; dredging may deepen and widen a channel and therefore decrease the water flow; canalisation &/or structures may alter flow speed and direction; managed realignment (e.g., seawalls) can alter tidal streams.
	Emergence regime changes - local	Events or activities that change how long and how often intertidal species are underwater or exposed during tides. For example, beach re-profiling could change gradients and therefore exposure times, dredging may change the natural tidal range, managed realignment can reduce the intertidal area. This excludes pressure from sea level rise.
	Oxygen changes	Changes in the oxygen levels in seawater, including marine deoxygenation (decreases in oxygen levels). Anthropogenic-induced marine deoxygenation can result from excessive nutrient additions (like nitrogen and phosphorous) into the marine environment (e.g., from agricultural runoff and wastewater), which can lead to algal blooms which consume oxygen when they decompose.
	pH changes	Activities that result in changes in the pH of marine waters. This includes the run-off of nitrogen-based fertilizers, which can indirectly affect pH levels through processes like eutrophication and the discharge of untreated or partially treated wastewater into the ocean, which can introduce various chemicals that alter the pH of marine waters.
	Wave exposure changes - local	Local changes in length, height and frequency of waves. Exposure on an open shore is dependent upon the distance of open seawater over which wind may blow to generate waves (the fetch) and the strength and incidence of winds. Anthropogenic sources of this pressure include artificial reefs, breakwaters, barrages, wrecks that can directly influence wave action or activities that may locally affect the incidence of winds, e.g., a dense network of wind turbines may have the potential to influence wave exposure, depending upon their location relative to the coastline.

Category Title	Pressure Title	Pressure Description
Pollution and other chemical changes	Non-synthetic compound contamination - Transition elements & organo-metals	The increase in the levels of transition elements compared with background concentrations, due to their input from land/riverine sources, by air or directly at sea. For marine sediments the main elements of concern are Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead and Zinc. Organo-metallic compounds such as the butyl tins (Tri butyl tin and its derivatives). These can be highly persistent and chronic exposure to low levels has adverse biological effects (e.g., imposex in molluscs).
	Non-synthetic compound contamination - Hydrocarbon & PAH contamination	Increases in the levels of these compounds compared with background concentrations. Naturally occurring compounds, complex mixtures of two basic molecular structures: straight chained aliphatic hydrocarbons (relatively low toxicity and susceptible to degradation) and multiple ringed aromatic hydrocarbons (higher toxicity and more resistant to degradation). These fall into three categories based on source (includes both aliphatics and polyaromatic hydrocarbons): petroleum hydrocarbons (from natural seeps, oil spills and surface water run-off), pyrogenic hydrocarbons (from combustion of coal, woods and petroleum) and biogenic hydrocarbons (from plants & animals). Ecological consequences include tainting, some are acutely toxic, and can cause carcinomas and growth defects.
	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	Increases in the levels of these compounds compared with background concentrations. Synthesised from a variety of industrial processes and commercial applications. Chlorinated compounds, which include polychlorinated biphenols (PCBs), dichlor-diphenyl-trichloroethane (DDT) & 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8- TCDD), are persistent and often very toxic. Pesticides vary greatly in structure, composition, environmental persistence and toxicity to non-target organisms. Includes insecticides, herbicides, rodenticides & fungicides. Pharmaceuticals and Personal Care Products originate from veterinary and human applications compiling a variety of products, including over the counter medications, fungicides, chemotherapy drugs and animal therapeutics, such as growth hormones. Due to their biologically active nature, high levels of consumption, known combined effects, and their detection in most aquatic environments they have become an emerging concern. Ecological consequences include physiological changes (e.g., growth defects, carcinomas).
	De-oxygenation	Any deoxygenation that is not directly associated with nutrient or organic enrichment. The lowering, temporarily or more permanently, of oxygen levels in the water or substrate due to anthropogenic causes (some areas may naturally be deoxygenated due to stagnation of water masses, e.g., inner basins of fjords). This is typically associated with nutrient and organic enrichment, but it can also derive from the release of ballast water or other stagnant waters (where organic or nutrient enrichment may be absent). Ballast waters may be deliberately deoxygenated via treatment with inert gases to kill non-indigenous species.
	Nutrient enrichment	Increased levels of nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Nutrients can enter marine waters by natural processes (e.g., decomposition of detritus, riverine, direct and atmospheric inputs) or anthropogenic sources (e.g.,

Category Title	Pressure Title	Pressure Description
		wastewater runoff, terrestrial/agricultural runoff, sewage discharges, aquaculture, atmospheric deposition). Nutrients can also enter marine regions from 'upstream' locations, e.g., via tidal currents to induce enrichment in the receiving area. Nutrient enrichment may lead to eutrophication (see also organic enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.
	Organic enrichment	Resulting from the degraded remains of dead biota & microbiota (land & sea), faecal matter from marine animals, flocculated colloidal organic matter and the degraded remains of sewage material, domestic wastes, industrial wastes etc. Organic matter can enter marine waters from sewage discharges, aquaculture or terrestrial/agricultural runoff. Black carbon comes from the products of incomplete combustion (PIC) of fossil fuels and vegetation. Organic enrichment may lead to eutrophication (see also nutrient enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.
	Radionuclide contamination	Introduction of radionuclide material, raising levels above background concentrations. Such materials can come from land or sea -based operations (e.g., oil platforms, medical sources) and historical disposal of radioactive waste from contaminated medical equipment and radium at sea.
Physical loss (permanent change)	Physical loss to land or freshwater habitat	The permanent loss of marine habitats. Associated activities are land claim, new coastal defences that encroach on and move the Mean High Water Springs mark seawards, dredging if it alters the position of the halocline. This excludes changes from one marine habitat type to another marine habitat type.
	Physical change to another seabed type	The permanent change of one marine habitat type to another marine habitat type, through the change in substratum, including to artificial (e.g., concrete). Associated activities include the installation of infrastructure (e.g., surface of platforms or wind farm foundations, marinas, coastal defences, pipelines and cables), the placement of scour protection where soft sediment habitats are replaced by hard/coarse substrate habitats, removal of coarse substrate (marine mineral extraction) and dredging where the residual habitat differs structurally from the activity state, creation of artificial reefs, mariculture, the protection of pipes and cables using rock dumping and mattressing techniques, placement of cuttings and piles from oil & gas activities. This pressure excludes dredging where the depth of sediment is changed locally but the sediment typology is not changed.
Physical damage (reversible change)	Temporary and/or reversible change of habitat structure (extraction)	Temporary and/or reversible change of habitat structure through habitat extraction, e.g., from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is similar to the pre-dredge structure and as such biological communities could re-colonise; or navigational dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed.

Category Title	Pressure Title	Pressure Description
	Disturbance of the surface of the seabed	The disturbance of sediments where there is limited or no loss of substrate from the system. The disruption or alteration of the seabed's top layer due to various activities. This can be caused by natural processes like hydrodynamics and bioturbation, as well as human activities such as bottom contact fishing gear, anchoring, propeller wash from vessels, aquaculture, port anchorage, dredging, the construction and maintenance of offshore installations. These activities can lead to changes in the geological, physical, and chemical conditions of the seabed, impacting the benthic (seafloor) ecosystems.
	Penetration and/or disturbance of the substrate below the surface of the seabed	The disturbance of sediments where there is limited or no loss of substrate from the system. The physical impact on the layers beneath the seabed's surface. This includes activities that penetrate or disturb the sediment, such as anchoring, taking of sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), certain fishing activities, e.g., scallop dredging, bottom trawling, compression of sediments, e.g., from the legs of a jack-up barge could also fit into this pressure type. These activities can cause changes in the physical structure and composition of the seabed, potentially impacting marine habitats and ecosystems.
	Changes in suspended solids	Changes in water clarity from sediment & organic particulate matter concentrations. It is related to activities disturbing or introducing sediment and/or organic particulate matter and mobilising it into the water column. Could be 'natural' land run-off and riverine discharges or from anthropogenic activities such as all forms of dredging, disposal at sea, cable and pipeline burial, secondary effects of construction work such as breakwaters. Particle size, hydrological energy (current speed & direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration. Salinity, turbulence, pH and temperature may result in flocculation of suspended organic matter.
	Siltation (sedimentation) rate changes	Alteration (increases or decreases) of the natural rates of siltation (sedimentation) through the settling out of silt/sediments suspended in the water column. Activities associated with this pressure type include mariculture, land claim, navigational dredging, disposal at sea, marine mineral extraction, cable and pipeline laying and various construction activities. It can result in short lived sediment concentration gradients and the accumulation of sediments on the sea floor. IS related to light smothering, where a thin layer of material covers something, restricting its access to air or light but not completely cutting it off.
Other physical pressures	Litter	Refers to any human-made solid material that is discarded, disposed of, or abandoned in the coastal marine environment or ocean. This includes items like plastics, metals, wood, rope, and fishing gear, as well as their broken-down pieces, such as microplastics. Ecological effects can be physical (smothering), biological (ingestion, including uptake of microplastics; entangling; physical damage; accumulation of chemicals) and/or chemical (leaching, contamination).

Category Title	Pressure Title	Pressure Description
	Electromagnetic changes	Localised electric and magnetic fields associated with operational power cables and telecommunication cables (if equipped with power relays). These cables may generate electric and magnetic fields that could alter behaviour and migration patterns of sensitive species (e.g., sharks and rays).
	Underwater noise changes	Increases over and above background noise levels (consisting of environmental noise (ambient) and incidental man-made/anthropogenic noise (apparent)) at a particular location. Species known to be affected are marine mammals and fish. Effects include hearing loss, discomfort, injury, and in extreme cases, death in addition to indirect effects such as acoustic masking and behavioural modification. The impact depends on factors like sound pressure, loudness, exposure level, and frequency. High amplitude and low-frequency sounds are particularly harmful. Noise can travel long distances (10s of kms) but is affected by water depth and seabed features. Noise levels associated with construction activities, such as pile-driving, are typically significantly greater than operational phases (i.e., shipping, operation of a wind farm).
	Introduction of light	Direct inputs of light from anthropogenic activities. This includes lighting on structures during construction or operation to allow 24 h working; new tourist facilities (e.g., promenade or pier lighting), lighting on oil & gas facilities etc. Ecological effects may be the diversion of bird species from migration routes if they are disorientated by or attracted to the lights. It is also possible that continuous lighting may lead to increased algal growth.
	Barrier to species movement	Obstacles that prevent animals from moving freely between different habitats. These barriers can disrupt migration, breeding, feeding, and other essential activities. Barriers include physical structures such as tidal barrages; infrastructure including offshore wind farms, mariculture setups; pollution where high levels of turbidity act as a barrier by inhibiting navigation; electromagnetic fields that some species find difficult to cross and habitat alteration that fragments habitats and makes it difficult for species to move between them. Includes upriver movements or movements across open waters. Species affected are mostly birds, fish, mammals.
	Death or injury by collision	Injury or mortality from collisions of biota with both static &/or moving structures. Examples include collision with rigs (e.g., birds), static screens in intake pipes (e.g., fish at power stations), wind turbine blades (e.g., birds), tidal devices (e.g., fish & mammals) and fishing vessels (birds).
Biological pressures	Visual disturbance	The disturbance of animals by anthropogenic activities. Examples include increased vessel movements, such as during construction phases for new infrastructure (bridges, cranes, port buildings etc), increased personnel movements, increased tourism, increased vehicular movements on shore disturbing bird roosting areas, seal haul out areas etc

Category Title	Pressure Title	Pressure Description
	Genetic modification & translocation of indigenous species	Genetic modification can be either deliberate (e.g., introduction of farmed individuals to the wild, GM food production), accidental (e.g., escapees from salmon farms or the translocation of GM species in ballast water) or a by-product of other activities (e.g., mutations associated with radionuclide contamination). Anthropogenic movement of native species to new regions can also introduce different genetic stock.
	Introduction or spread of non-indigenous species	The introduction of non-indigenous species, e.g., Asian paddle crab, Mediterranean fan worm, exotic Caulerpa, and their subsequent spreading. Ballast water, hull fouling, stepping stone effects (e.g., aquaculture farms) may facilitate the spread of such species.
	Introduction of microbial pathogens	The introduction of microbial pathogens via untreated or insufficiently treated effluent discharges, run-off from terrestrial sources (e.g., toxoplasmosis) and vessels, ballast water releases. Escapees (e.g., farmed salmon) could be infected and spread pathogens. Aquaculture could release contaminated faecal matter, from which pathogens could enter the food chain.
	Removal of target species	The removal of target species through commercial exploitation of fish & shellfish stocks, recreational fishing, bioprospecting and scientific sampling. The physical effects of fishing gear on seabed communities are addressed by the "abrasion" pressure type, so this pressure addresses the direct removal / harvesting of biota. Ecological consequences include the sustainability of stocks, impacting energy flows through food webs and the size and age composition within fish stocks.
	Removal of non-target species	By-catch associated with fishing activities, bioprospecting, research, mineral extraction and dredging etc. This pressure addresses the direct removal of individuals, the physical effects of fishing gear on seabed communities are addressed by the "abrasion" pressure type. Ecological consequences include disruption of food webs and changes to the population dynamics of marine biota.

Appendix C Matrix evidence

- Abanades, J., Greaves, D., Iglesias, G. (2015) Wave farm impact on beach modal state. *Marine Geology*, 361: 126-135. <https://doi.org/10.1016/j.margeo.2015.01.008>
- Adams, T.P., Miller, R.G., Aleynik, D., Burrows, M.T. (2014) Offshore marine renewable energy devices as stepping stones across biogeographical boundaries. *Journal of Applied Ecology*, 51(2): 330-338. <https://doi.org/10.1111/1365-2664.12207>
- Addy, J.M., Hartley, J.P., Tibbetts, P.J.C. (1984) Ecological effects of low toxicity oil-based mud drilling in the Beatrice oilfield. *Marine Pollution Bulletin*, 15(12): 429-436. [https://doi.org/10.1016/0025-326X\(84\)90141-3](https://doi.org/10.1016/0025-326X(84)90141-3)
- Adel Hussein, A. (2023) The Connection between the Impacts of Desalination and the Surrounding Environment. In: R. Karthick & Z. Akif (Eds). *Desalination*. IntechOpen, Rijeka: Ch. 4. <https://doi.org/10.5772/intechopen.110140>
- Affatati, A., Camerlenghi, A. (2023) Effects of marine seismic surveys on free-ranging fauna: a systematic literature review. *Frontiers in Marine Science*, 10. <https://doi.org/10.3389/fmars.2023.1222523>
- Airoldi, L., Turon, X., Perkol-Finkel, S., Rius, M. (2015) Corridors for aliens but not for natives: effects of marine urban sprawl at a regional scale. *Diversity and Distributions*, 21(7): 755-768. <https://doi.org/10.1111/ddi.12301>
- Allan, S., Russell, G. (2017) Proposed Wharf And Dredging Project Resource Consent Applications and Description and Assessment Of Effects On The Environment. Prepared for Port of Napier Ltd: 245. <https://www.hbrc.govt.nz/assets/Document-Library/Consents/Port-of-Napier/Vol-1/FINAL-Wharf-Development-Applications-and-Assessment-of-Environmental-Effects-29-November-2017.pdf>
- Bakke, T., Klungsøyr, J., Sanni, S. (2013) Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry. *Marine Environmental Research*, 92: 154-169. <https://doi.org/10.1016/j.marenvres.2013.09.012>
- Battershill, C.N., Ross, P.R., Schiel, D.R. (2016) The MV Rena shipwreck: time-critical scientific response and environmental legacies. *New Zealand Journal of Marine and Freshwater Research*, 50(1): 173-182. <https://doi.org/10.1080/00288330.2015.1134593>
- Benjamin, E., Handley, S., Hale, R., Toone, T., Jeffs, A., Hillman, J. (2022) Biodiversity associated with restored small-scale mussel habitats has restoration decision implications. *Biodiversity and Conservation*, 31: 2833-2855. <https://doi.org/10.1007/s10531-022-02462-1>
- Benjamin, E.D., Handley, S.J., Jeffs, A., Olsen, L., Toone, T.A., Hillman, J.R. (2023) Testing habitat suitability for shellfish restoration with small-scale pilot experiments. *Conservation Science and Practice*, 5(2): e12878. <https://doi.org/10.1111/csp2.12878>
- Benjamins, S., Harnois, V., Smith, H.C.M., Johanning, L., Greenhill, L., Carter, C. and, Wilson, B. (2014) Understanding the potential for marine megafauna entanglement risk from marine renewable energy developments Scottish Natural Heritage Commissioned

- Report, No. 791. <https://www.nature.scot/sites/default/files/2017-07/Publication%202014%20-%20SNH%20Commissioned%20Report%20791%20-%20Understanding%20the%20potential%20for%20marine%20megafauna%20entanglement%20risk%20from%20renewable%20marine%20energy%20developments.pdf>
- Bergström, L., Kautsky, L., Malm, T., Rosenberg, R., Wahlberg, M., Åstrand Capetillo, N., Wilhelmsson, D. (2014) Effects of offshore wind farms on marine wildlife—a generalized impact assessment. *Environmental Research Letters*, 9(3): 034012. <https://doi.org/10.1088/1748-9326/9/3/034012>
- Bioresearches (2020) Assessment of Ecological Effects: For Sand Extraction from the Midshore Pakiri Embayment. Report for McCallum Brothers Limited: 109. <https://www.aucklandcouncil.govt.nz/ResourceConsentDocuments/BUN60369079%20Ecological%20Effects.pdf>
- Boffa Miskell Limited (2016) Lyttelton Port Company Channel Deepening Project: Marine Avifauna Assessment. Prepared for Lyttelton Port Company Limited. <https://www.lpc.co.nz/wp-content/uploads/2016/06/Appendix-17.pdf>
- Boyle, M.C., Jillett, J.B., Mladenov, P.V. (2001) Intertidal communities in Doubtful Sound, New Zealand: Changes over time. *New Zealand Journal of Marine and Freshwater Research*, 35(4): 663-673. <https://doi.org/10.1080/00288330.2001.9517033>
- Broad, A., Rees, M.J., Davis, A.R. (2020) Anchor and chain scour as disturbance agents in benthic environments: trends in the literature and charting a course to more sustainable boating and shipping. *Marine Pollution Bulletin*, 161: 111683. <https://doi.org/10.1016/j.marpolbul.2020.111683>
- Brooks, K.M., Mahnken, C.V.W. (2003a) Interactions of Atlantic salmon in the Pacific northwest environment: II. Organic wastes. *Fisheries Research*, 62(3): 255-293. [https://doi.org/10.1016/S0165-7836\(03\)00064-X](https://doi.org/10.1016/S0165-7836(03)00064-X)
- Brooks, K.M., Mahnken, C.V.W. (2003b) Interactions of Atlantic salmon in the Pacific Northwest environment: III. Accumulation of zinc and copper. *Fisheries Research*, 62(3): 295-305. [https://doi.org/10.1016/S0165-7836\(03\)00065-1](https://doi.org/10.1016/S0165-7836(03)00065-1)
- Brown NZ Ltd (2020) Pakiri Mid-Shore Sand Extraction Project: Landscape Effects Assessment. McCallum Brothers Ltd. <https://www.aucklandcouncil.govt.nz/ResourceConsentDocuments/BUN60369079%20Landscape%20Ass.pdf>
- Burns, J., Hempston, N. (2021) Whanganui Port Wharf: Aquatic Assessment of Environmental Effects. EOS Ecology Report, No. WHA01-21045-01: 44. <https://www.whanganui.govt.nz/files/assets/public/v/1/port-revitalisation-documents/consent-applications/wharf-replacement-resource-consent/appendix-b-eos-ecology-report.pdf>
- Burrige, L., Weis, J.S., Cabello, F., Pizarro, J., Bostick, K. (2010) Chemical use in salmon aquaculture: A review of current practices and possible environmental effects. *Aquaculture*, 306(1): 7-23. <https://doi.org/10.1016/j.aquaculture.2010.05.020>

- Butler, D. (2003) Possible impacts of marine farming of mussels (*Perna canaliculus*) on king shags (*Leucocarbo carunculatus*). DOC Science Internal Series, 111.
<https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=264a7c429caff7fb2e6b4c7cc1aff42eb923aecf>
- Cada, G., Ahlgrimm, J., Bahleda, M., Bigford, T., Stavrakas, S., Hall, D., Moursund, R., Sale, M. (2007) Potential Impacts of Hydrokinetic and Wave Energy Conversion Technologies on Aquatic Environments. *Fisheries*, 32: 174-181. [https://doi.org/10.1577/1548-8446\(2007\)32\[174:PIOHAW\]2.0.CO;2](https://doi.org/10.1577/1548-8446(2007)32[174:PIOHAW]2.0.CO;2)
- Campbell, I., Macleod, A., Sahlmann, C., Neves, L., Funderud, J., Øverland, M., Hughes, A.D., Stanley, M. (2019) The Environmental Risks Associated with the Development of Seaweed Farming in Europe - Prioritizing Key Knowledge Gaps. *Frontiers in Marine Science*, 6. <https://doi.org/10.3389/fmars.2019.00107>
- Campbell, M.L., King, S., Heppenstall, L.D., van Gool, E., Martin, R., Hewitt, C.L. (2017) Aquaculture and urban marine structures facilitate native and non-indigenous species transfer through generation and accumulation of marine debris. *Marine Pollution Bulletin*, 123(1): 304-312. <https://doi.org/10.1016/j.marpolbul.2017.08.040>
- Carreño, A., Lloret, J. (2021) Environmental impacts of increasing leisure boating activity in Mediterranean coastal waters. *Ocean & Coastal Management*, 209: 105693. <https://doi.org/10.1016/j.ocecoaman.2021.105693>
- Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., Bruce, B. (2017) A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. *Marine Pollution Bulletin*, 114(1): 9-24. <https://doi.org/10.1016/j.marpolbul.2016.11.038>
- Cedre, Transport Canada (2012) Understanding chemical pollution at sea. Learning Guide: 93. <https://www.chemical-pollution.com/medias/pdf/learning-guide/understanding-chemical-pollution-at-sea.pdf>
- Chen, Q., Wu, W., Guo, Y., Li, J., Wei, F. (2022) Environmental impact, treatment technology and monitoring system of ship domestic sewage: A review. *Science of the Total Environment*, 811: 151410. <https://doi.org/10.1016/j.scitotenv.2021.151410>
- Chou, L.M. (1997) Artificial Reefs of Southeast Asia - Do They Enhance or Degrade the Marine Environment? *Environmental Monitoring and Assessment*, 44(1): 45-52. <https://doi.org/10.1023/A:1005759818050>
- Clark, D., Berthelsen, A. (2021) Review of the potential for low impact seagrass restoration in Aotearoa New Zealand. Cawthron Report, No. 3697: 53. <https://www.envirolink.govt.nz/assets/Envirolink/2146-NLCC119-Review-of-the-potential-for-low-impact-seagrass-restoration-in-Aotearoa-New-Zealand.pdf>
- Clark, D., Newcombe, E., Clement, D., Magnusson, M., Lawton, R., Glasson, R., Major, R., Adams, S. (2021) Stocktake and characterisation of Aotearoa New Zealand's seaweed sector: Environmental effects of seaweed wild-harvest and aquaculture. Report for Sustainable Seas National Science Challenge Project Building a seaweed sector: developing a seaweed sector framework for Aotearoa New Zealand. (Project code 2.5).

<https://climateandnature.org.nz/wp-content/uploads/2021/11/Enviro-effects-seaweed-harvet-and-aq.pdf>

- Clement, D., Johnston, O. (2019) Pakiri sand extraction: marine mammal assessment of effects. Prepared for McCallum Brothers Ltd. Cawthron Report: 40.
<https://www.aucklandcouncil.govt.nz/ResourceConsentDocuments/BUN60352951%20Ass.%20Marine%20Mammal%20Effs.pdf>
- Clement, D.M. (2013) Effects on Marine Mammals. Literature Review of ecological effects of aquaculture. Ministry for Primary Industries, Wellington.
<https://www.mpi.govt.nz/dmsdocument/3752-Literature-Review-of-Ecological-Effects-of-Aquaculture-Chapter-4-Effects-on-Marine-Mammals>
- Clement, D.M., Keeley, N., Sneddon, R. (2010) Ecological Relevance of Copper (Cu) and Zinc (Zn) in Sediments Beneath Fish Farms in New Zealand. Cawthron Report, No. 1805: 48.
<https://www.envirolink.govt.nz/assets/Envirolink/877-MLDC48-Ecological-relevance-of-Cu-and-Zn-in-sediments-beneath-fish-farms-in-NZ.pdf>
- Constantine, R., Johnson, M., Riekkola, L., Jervis, S., Kozmian-Ledward, L., Dennis, T., Torres, L.G., Aguilar de Soto, N. (2015) Mitigation of vessel-strike mortality of endangered Bryde's whales in the Hauraki Gulf, New Zealand. *Biological Conservation*, 186: 149-157.
<https://doi.org/10.1016/j.biocon.2015.03.008>
- Copping, A., Battey, H., Brown-Saracino, J., Massaua, M., Smith, C. (2014) An international assessment of the environmental effects of marine energy development. *Ocean & Coastal Management*, 99: 3-13. <https://doi.org/10.1016/j.ocecoaman.2014.04.002>
- Copping, A., Hemery, L. (2020) OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). <https://doi.org/10.2172/1632878>
- Cordes, E.E., Jones, D.O.B., Schlacher, T.A., Amon, D.J., Bernardino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., Gates, A.R., Génio, L., Gobin, J., Henry, L.-A., Herrera, S., Hoyt, S., Joye, M., Kark, S., Mestre, N.C., Metaxas, A., Pfeifer, S., Sink, K., Sweetman, A.K., Witte, U. (2016) Environmental Impacts of the Deep-Water Oil and Gas Industry: A Review to Guide Management Strategies. *Frontiers in Environmental Science*, 4. <https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2016.00058>
- Cornelisen, C. (2011) The New Zealand King Salmon Company Limited: Assessment of Environmental Effects - Submerged Artificial Lighting. Cawthron Report, No. 1982: 17.
<https://www.epa.govt.nz/assets/FileAPI/proposal/NSP000002/Applicants-proposal-documents/9e7954ad98/Appendix-12-Artificial-Lighting-Report.pdf>
- Cornelisen, C. (2013) Effects on Wild Fish. Literature review of ecological effects of aquaculture. Ministry for Primary Industries, Wellington.
<https://www.mpi.govt.nz/dmsdocument/3753-Literature-Review-of-Ecological-Effects-of-Aquaculture-Chapter-5-Effects-on-Wild-Fish>
- Cornwall, C.E., Pilditch, C., Hepburn, C., Hurd, C.L. (2015) Canopy macroalgae influence understorey corallines' metabolic control of near-surface pH and oxygen concentration.

- Marine Ecology Progress Series, 525: 81-95. <https://www.int-res.com/articles/meps2015/525/m525p081.pdf>
- da Silva, T.D., Mullarney, J.C., Pilditch, C.A., Coco, G. (2024) The interaction between vegetation patchiness and tidal flows in a shortleaf seagrass meadow. *Limnology and Oceanography*, 69(10): 2422-2435. <https://doi.org/10.1002/lno.12679>
- Daan, R., Mulder, M. (1996) On the short-term and long-term impact of drilling activities in the Dutch sector of the North Sea. *ICES Journal of Marine Science*, 53(6): 1036-1044. <https://doi.org/10.1006/jmsc.1996.0129>
- Darbra, R.M., Ronza, A., Stojanovic, T.A., Wooldridge, C., Casal, J. (2005) A procedure for identifying significant environmental aspects in sea ports. *Marine Pollution Bulletin*, 50(8): 866-874. <https://doi.org/10.1016/j.marpolbul.2005.04.037>
- Davis, A.R., Broad, A., Gullett, W., Reveley, J., Steele, C., Schofield, C. (2016) Anchors away? The impacts of anchor scour by ocean-going vessels and potential response options. *Marine Policy*, 73: 1-7. <https://doi.org/10.1016/j.marpol.2016.07.021>
- de Baar, H.J.W., Boyd, P.W., Coale, K.H., Landry, M.R., Tsuda, A., Assmy, P., Bakker, D.C.E., Bozec, Y., Barber, R.T., Brzezinski, M.A., Buesseler, K.O., Boyé, M., Croot, P.L., Gervais, F., Gorbunov, M.Y., Harrison, P.J., Hiscock, W.T., Laan, P., Lancelot, C., Law, C.S., Levasseur, M., Marchetti, A., Millero, F.J., Nishioka, J., Nojiri, Y., van Oijen, T., Riebesell, U., Rijkenberg, M.J.A., Saito, H., Takeda, S., Timmermans, K.R., Veldhuis, M.J.W., Waite, A.M., Wong, C.-S. (2005) Synthesis of iron fertilization experiments: From the Iron Age in the Age of Enlightenment. *Journal of Geophysical Research: Oceans*, 110(C9). <https://doi.org/10.1029/2004JC002601>
- De Mesel, I., Kerckhof, F., Norro, A., Rumes, B., Degraer, S. (2015) Succession and seasonal dynamics of the epifauna community on offshore wind farm foundations and their role as stepping stones for non-indigenous species. *Hydrobiologia*, 756(1): 37-50. <https://doi.org/10.1007/s10750-014-2157-1>
- Dempsey, T., Ross, P.M., Hartland, A., McSweeney, C., Battershill, C.N. (2016) Measurement of shipwreck-derived waterborne trace metals using DGT samplers. *New Zealand Journal of Marine and Freshwater Research*, 50(1): 115-130. 10.1080/00288330.2015.1127829
- Department of Conservation (2013) 2013 Code of Conduct for Minimising Acoustic Disturbance to Marine Mammals from Seismic Survey Operations: 36. <https://www.doc.govt.nz/documents/conservation/native-animals/marine-mammals/seismic-survey-code-of-conduct.pdf>
- Derraik, J.G.B. (2002) The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, 44(9): 842-852. [https://doi.org/10.1016/S0025-326X\(02\)00220-5](https://doi.org/10.1016/S0025-326X(02)00220-5)
- Di Iorio, L., Clark, C.W. (2010) Exposure to seismic survey alters blue whale acoustic communication. *Biology Letters*, 6(1): 51-54. <https://doi.org/10.1098/rsbl.2009.0651>
- Donázar-Aramendía, I., Megina, C., Miró, J.M., Florido, M., Reyes-Martínez, M.J., Olaya-Ponzzone, L., García-Gómez, J.C. (2024) Environmental effects of maintenance dredging

- works in a highly modified estuary: A short-term approach. *Ocean & Coastal Management*, 258: 107394. <https://doi.org/10.1016/j.ocecoaman.2024.107394>
- Donázar-Aramendía, I., Reyes-Martínez, M.J., Megina, C., Florido, M., García-Gómez, J.C. (2025) Assessing the effects of electromagnetic fields generated by submarine power cables on the soft-bottom community: An ecological in-situ study. *Environmental Research*, 266: 120573. <https://doi.org/10.1016/j.envres.2024.120573>
- Dong, Y., Liu, Y., Hu, C., MacDonald, I.R., Lu, Y. (2022) Chronic oiling in global oceans. *Science*, 376(6599): 1300-1304. <https://doi.org/10.1126/science.abm5940>
- Drazen, J.C., Smith, C.R., Gjerde, K.M., Haddock, S.H.D., Carter, G.S., Choy, C.A., Clark, M.R., Dutrieux, P., Goetze, E., Hauton, C., Hatta, M., Koslow, J.A., Leitner, A.B., Pacini, A., Perelman, J.N., Peacock, T., Sutton, T.T., Watling, L., Yamamoto, H. (2020) Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining. *Proceedings of the National Academy of Sciences*, 117(30): 17455-17460. <https://doi.org/10.1073/pnas.2011914117>
- Duarte, C.M., Chapuis, L., Collin, S.P., Costa, D.P., Devassy, R.P., Eguiluz, V.M., Erbe, C., Gordon, T.A.C., Halpern, B.S., Harding, H.R., Havlik, M.N., Meekan, M., Merchant, N.D., Miksis-Olds, J.L., Parsons, M., Predragovic, M., Radford, A.N., Radford, C.A., Simpson, S.D., Slabbekoorn, H., Staaterman, E., Van Opzeeland, I.C., Winderen, J., Zhang, X., Juanes, F. (2021) The soundscape of the Anthropocene ocean. *Science*, 371(6529): eaba4658. <https://doi.org/10.1126/science.aba4658>
- Easton, A., Komyakova, V., Coughlin, T. (2024) Evaluating ecological risk in artificial habitat failure: A systematic review and risk assessment considering noise and light pollution in the marine environment. *Environmental Impact Assessment Review*, 107: 107560. <https://doi.org/10.1016/j.eiar.2024.107560>
- Ebdon, P., Riekkola, L., Constantine, R. (2020) Testing the efficacy of ship strike mitigation for whales in the Hauraki Gulf, New Zealand. *Ocean & Coastal Management*, 184: 105034. <https://doi.org/10.1016/j.ocecoaman.2019.105034>
- Fletcher, L., Johnston, O. (2020) Marine biosecurity risks arising from activities/stressors within the Waikato coastal marine area. Waikato Regional Council Technical Report, 2020/09: 111. <https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/TR2020-09.pdf>
- Floeter, J., van Beusekom, J.E.E., Auch, D., Callies, U., Carpenter, J., Dudeck, T., Eberle, S., Eckhardt, A., Gloe, D., Hänselmann, K., Hufnagl, M., Janßen, S., Lenhart, H., Möller, K.O., North, R.P., Pohlmann, T., Riethmüller, R., Schulz, S., Spreizenbarth, S., Temming, A., Walter, B., Zielinski, O., Möllmann, C. (2017) Pelagic effects of offshore wind farm foundations in the stratified North Sea. *Progress in Oceanography*, 156: 154-173. <https://doi.org/10.1016/j.pocean.2017.07.003>
- Ford, R. (2013a) Effects from Genetic Modification or Polyploidy. Literature Review of the Ecological Effects of Aquaculture. Ministry for Primary Industries, Wellington. <https://www.mpi.govt.nz/dmsdocument/3757-Literature-Review-of-Ecological-Effects-of-Aquaculture-Chapter-9-Effects-from-Genetic-Modification-or-Polyploidy>

- Ford, R. (2013b) Escapee Effects. Literature Review of the Ecological Effects of Aquaculture. Ministry for Primary Industries, Wellington.
<https://www.mpi.govt.nz/dmsdocument/3756-Literature-Review-of-Ecological-Effects-of-Aquaculture-Chapter-8-Escapee-Effects>
- Forrest, B., Hopkins, G., Webb, S., Tremblay, L. (2011a) Overview of Marine Biosecurity Risks from Finfish Aquaculture Development in the Waikato Region Waikato Regional Council Technical Report, 2011/22.
<https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/TR201122.pdf>
- Forrest, B.M., Creese, R.G. (2006) Benthic Impacts of Intertidal Oyster Culture, with Consideration of Taxonomic Sufficiency. Environmental Monitoring and Assessment, 112(1): 159-176. <https://doi.org/10.1007/s10661-006-0359-3>
- Forrest, B.M., Elmetri, I., Clark, K. (2007a) Review of the Ecological Effects of Intertidal Oyster Aquaculture Cawthron Report, No. 1275: 25.
<https://www.envirolink.govt.nz/assets/Envirolink/216-NLRC25.pdf>
- Forrest, B.M., Keeley, N., Gillespie, P.A., Hopkins, G., Knight, B., Govier, D. (2007b) Review of the ecological effects of marine finfish aquaculture: final report. Cawthron Report, 1285: 71.
- Forrest, B.M., Keeley, N.B., Hopkins, G.A., Webb, S.C., Clement, D.M. (2009) Bivalve aquaculture in estuaries: Review and synthesis of oyster cultivation effects. Aquaculture, 298(1): 1-15. <https://doi.org/10.1016/j.aquaculture.2009.09.032>
- Forrest, R., Keeley, N., Dunmore, R.A. (2011b) Environmental Impacts of the Te Pangu Bay Salmon Farm: Annual Monitoring 2010. Cawthron Report No., 1913.
<https://data.marlborough.govt.nz/trim/api/trim/get?id=1545824&company=mdc&application=smtechreports>
- Frid, C., Andonegi, E., Depestele, J., Judd, A., Rihan, D., Rogers, S.I., Kenchington, E. (2012) The environmental interactions of tidal and wave energy generation devices. Environmental Impact Assessment Review, 32(1): 133-139.
<https://doi.org/10.1016/j.eiar.2011.06.002>
- Gabel, F., Lorenz, S., Stoll, S. (2017) Effects of ship-induced waves on aquatic ecosystems. Science of the Total Environment, 601-602: 926-939.
<https://doi.org/10.1016/j.scitotenv.2017.05.206>
- Gausepohl, F., Hennke, A., Schoening, T., Köser, K., Greinert, J. (2020) Scars in the abyss: reconstructing sequence, location and temporal change of the 78 plough tracks of the 1989 DISCOL deep-sea disturbance experiment in the Peru Basin. Biogeosciences, 17(6): 1463-1493. <https://doi.org/10.5194/bg-17-1463-2020>
- Gibbs, M.T. (2004) Interactions between bivalve shellfish farms and fishery resources. Aquaculture, 240(1): 267-296. <https://doi.org/10.1016/j.aquaculture.2004.06.038>
- Gibbs, M.T., Bowman, M.J., Dietrich, D.E. (2000) Maintenance of Near-Surface Stratification in Doubtful Sound, a New Zealand Fjord. Estuarine, Coastal and Shelf Science, 51(6): 683-704. <https://doi.org/10.1006/ecss.2000.0716>

- Giles, H., Pilditch, C.A. (2006) Effects of mussel (*Perna canaliculus*) biodeposit decomposition on benthic respiration and nutrient fluxes. *Marine Biology*, 150(2): 261-271. <https://doi.org/10.1007/s00227-006-0348-7>
- Giles, H., Pilditch, C.A., Bell, D.G. (2006) Sedimentation from mussel (*Perna canaliculus*) culture in the Firth of Thames, New Zealand: Impacts on sediment oxygen and nutrient fluxes. *Aquaculture*, 261(1): 125-140. <https://doi.org/10.1016/j.aquaculture.2006.06.048>
- Gill, A.B. (2005) Offshore renewable energy: ecological implications of generating electricity in the coastal zone. *Journal of Applied Ecology*, 42(4): 605-615. <https://doi.org/10.1111/j.1365-2664.2005.01060.x>
- Glibert, P.M., Azanza, R., Burford, M., Furuya, K., Abal, E., Al-Azri, A., Al-Yamani, F., Andersen, P., Anderson, D.M., Beardall, J., Berg, G.M., Brand, L., Bronk, D., Brookes, J., Burkholder, J.M., Cembella, A., Cochlan, W.P., Collier, J.L., Collos, Y., Diaz, R., Doblin, M., Drennen, T., Dyhrman, S., Fukuyo, Y., Furnas, M., Galloway, J., Granéli, E., Ha, D.V., Hallegraeff, G., Harrison, J., Harrison, P.J., Heil, C.A., Heimann, K., Howarth, R., Jauzein, C., Kana, A.A., Kana, T.M., Kim, H., Kudela, R., Legrand, C., Mallin, M., Mulholland, M., Murray, S., O'Neil, J., Pitcher, G., Qi, Y., Rabalais, N., Raine, R., Seitzinger, S., Salomon, P.S., Solomon, C., Stoecker, D.K., Usup, G., Wilson, J., Yin, K., Zhou, M., Zhu, M. (2008) Ocean urea fertilization for carbon credits poses high ecological risks. *Marine Pollution Bulletin*, 56(6): 1049-1056. <https://doi.org/10.1016/j.marpolbul.2008.03.010>
- Golder Associates (NZ) Ltd (2014a) Chatham Rise Sediments: Review of Sediment Chemistry and Effects of Mining: 95. <https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000006/Applicants-proposal-documents/f267470905/EEZ000006-Appendix11-Golder-2014a-Sediment-Chemistry-May-2014.pdf>
- Golder Associates (NZ) Ltd (2014b) Proposed Mining Operation, Chatham Rise. Marine Consent Application and Environmental Impact Assessment: Non-technical Summary. Chatham Rock Phosphate Limited: 16. https://static1.squarespace.com/static/51d24098e4b0d519d0c065f5/t/5782ea98be6594c387f68478/1468197553465/1178207517_Rev2_CRP_Non-tech%2BSummary_May%2B2014%2BFINAL.pdf
- Goring, D. (2016) Effects of Channel Deepening Project on Waves and Tidal Currents in Lyttelton Harbour/Whakaraupō. Mulgor Consulting Client Report, 2016/2: 60. <https://www.lpc.co.nz/wp-content/uploads/2016/06/Appendix-14.pdf>
- Guarnieri, A., Saremi, S., Pedroncini, A., Jensen, J.H., Torretta, S., Vaccari, M., Vincenzi, C. (2021) Effects of marine traffic on sediment erosion and accumulation in ports: a new model-based methodology. *Ocean Sci.*, 17(2): 411-430. <https://doi.org/10.5194/os-17-411-2021>
- Hale, R., Depree, C., Broekhuizen, N. (2023) Simulating fish farm enrichment and fallowing impacts reveals unequal biogeochemical recovery of benthic variables. *Aquaculture Environment Interactions*, 15: 115-131. <https://www.int-res.com/abstracts/aei/v15/p115-131/>

- Hale, R., Thompson, D., Brough, T., Kregting, L., Hayden, M., Parsons, D., Nodder, S.D., Beaumont, J., Anderson, O., Stevens, C. (2024) Environmental implications of future offshore renewable energy development in Aotearoa New Zealand. *Journal of the Royal Society of New Zealand*: 1-34. <https://doi.org/10.1080/03036758.2024.2406829>
- Hamilton, S.L., Elliott, M.S., deVries, M.S., Adelaars, J., Rintoul, M.D., Graham, M.H. (2022) Integrated multi-trophic aquaculture mitigates the effects of ocean acidification: Seaweeds raise system pH and improve growth of juvenile abalone. *Aquaculture*, 560: 738571. <https://doi.org/10.1016/j.aquaculture.2022.738571>
- Hartstein, N.D., Rowden, A.A. (2004) Effect of biodeposits from mussel culture on macroinvertebrate assemblages at sites of different hydrodynamic regime. *Marine Environmental Research*, 57(5): 339-357. <https://doi.org/10.1016/j.marenvres.2003.11.003>
- Hastings, K., Hesp, P., Kendrick, G.A. (1995) Seagrass loss associated with boat moorings at Rottnest Island, Western Australia. *Ocean & Coastal Management*, 26(3): 225-246. [https://doi.org/10.1016/0964-5691\(95\)00012-Q](https://doi.org/10.1016/0964-5691(95)00012-Q)
- Heery, E.C., Bishop, M.J., Critchley, L.P., Bugnot, A.B., Airoldi, L., Mayer-Pinto, M., Sheehan, E.V., Coleman, R.A., Loke, L.H.L., Johnston, E.L., Komyakova, V., Morris, R.L., Strain, E.M.A., Naylor, L.A., Dafforn, K.A. (2017) Identifying the consequences of ocean sprawl for sedimentary habitats. *Journal of Experimental Marine Biology and Ecology*, 492: 31-48. <https://doi.org/10.1016/j.jembe.2017.01.020>
- Hernández, M., Dawson, S., Pavanato, H., Leunissen, E., Rayment, W. (2024) Using passive acoustic monitoring to assess the overlap between endemic endangered Hector's dolphins and mussel farms in the Banks Peninsula Marine Mammal Sanctuary, New Zealand. *Aquatic Conservation Marine and Freshwater Ecosystems*, 34: e4207. <https://doi.org/10.1002/aqc.4207>
- Hess-Erga, O.-K., Moreno-Andrés, J., Enger, Ø., Vadstein, O. (2019) Microorganisms in ballast water: Disinfection, community dynamics, and implications for management. *Science of the Total Environment*, 657: 704-716. <https://doi.org/10.1016/j.scitotenv.2018.12.004>
- Hildebrand, J.A. (2009) Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series*, 395: 5-20. <https://www.int-res.com/abstracts/meps/v395/p5-20/>
- Hilliam, K., Treml, E.A., Stevenson, S., Floerl, O. (2024) Recreational vessel networks reveal potential hot spots for marine pest introduction and spread. *Journal of Applied Ecology*, 61(7): 1716-1727. <https://doi.org/10.1111/1365-2664.14660>
- Howarth, L., Major, R. (2023) Key environmental considerations for seaweed aquaculture in Aotearoa New Zealand. Sustainable Seas National Science Challenge. <https://www.sustainableseaschallenge.co.nz/tools-and-resources/key-environmental-considerations-for-seaweed-aquaculture/>

- Hutchison, Z.L., Gill, A.B., Sigray, P., He, H., King, J.W. (2020a) Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom-dwelling marine species. *Scientific Reports*, 10(1): 4219. <https://doi.org/10.1038/s41598-020-60793-x>
- Hutchison, Z.L., Secor, D.H., Gill, A.B. (2020b) The Interaction Between Resource Species and Electromagnetic Fields Associated with Electricity Production by Offshore Wind Farms. *Oceanography*, 33(4): 96-107. <https://doi.org/10.5670/oceanog.2020.409>
- Hylén, A., Taylor, D., Kononets, M., Lindegarth, M., Stedt, A., Bonaglia, S., Bergström, P. (2021) In situ characterization of benthic fluxes and denitrification efficiency in a newly re-established mussel farm. *Science of the Total Environment*, 782: 146853. <https://doi.org/10.1016/j.scitotenv.2021.146853>
- Inglis, G.J., Gust, N. (2003) Potential indirect effects of shellfish culture on the reproductive success of benthic predators. *Journal of Applied Ecology*, 40(6): 1077-1089. <https://doi.org/10.1111/j.1365-2664.2003.00860.x>
- Jacobson, P.T., Amaral, P.I.S.V., Castro-Santos, T., Giza, D., Haro, A.J., Hecker, G., McMahon, B., Perkins, N., Pioppi2, N. (2012) Environmental Effects of Hydrokinetic Turbines on Fish: Desktop and Laboratory Flume Studies. Electric Power Research Institute: 220. https://www.energy.gov/sites/prod/files/2013/12/f5/epri_turbine_effects_on_fish_2012.pdf
- Jones, E., Qadir, M., van Vliet, M.T.H., Smakhtin, V., Kang, S.-m. (2019) The state of desalination and brine production: A global outlook. *Science of the Total Environment*, 657: 1343-1356. <https://doi.org/10.1016/j.scitotenv.2018.12.076>
- Kadir, A., Istadi, I., Subagio, A., Iskendar, I., Waluyo, W., Muis, A., Kartikasari, D., Sadiyah, S., Widagdo, A.B., Helios, M.P., Nasir, M., Nurhadi, N. (2024) Ship Propeller Rotation Threshold to Prevent Erosion and Sedimentation in Coastal Waters. *Journal of Marine Science and Application*, 23(4): 798-811. <https://doi.org/10.1007/s11804-024-00470-x>
- Kaspar, H.F., Gillespie, P.A., Boyer, I.C., MacKenzie, A.L. (1985) Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound, Marlborough Sounds, New Zealand. *Marine Biology*, 85(2): 127-136. <https://doi.org/10.1007/BF00397431>
- Keeley, N., Forrest, B., Hopkins, G., Gillespie, P.A., Knight, B., Webb, S., Clement, D.M., Gardner, J. (2009) Sustainable Aquaculture in New Zealand: Review of the Ecological Effects of Farming Shellfish and Other Non-fish Species. Cawthron Report, No. 1476: 150. <https://www.mpi.govt.nz/dmsdocument/15868-Review-ecological-effects-farming-shellfish>
- Kery, S.M., Stauffer, J. (2015) Hydrodynamics related to shipwreck taphonomy. OCEANS 2015 - MTS/IEEE Washington, 19-22 Oct. 2015.
- Kingston, P.F. (1992) Impact of offshore oil production installations on the benthos of the North Sea. *ICES Journal of Marine Science*, 49(1): 45-53. <https://doi.org/10.1093/icesjms/49.1.45>

- Kirchgeorg, T., Weinberg, I., Hörnig, M., Baier, R., Schmid, M.J., Brockmeyer, B. (2018) Emissions from corrosion protection systems of offshore wind farms: Evaluation of the potential impact on the marine environment. *Marine Pollution Bulletin*, 136: 257-268. <https://doi.org/10.1016/j.marpolbul.2018.08.058>
- Kubale, A. (2020) Pakiri Sand Extraction Consent Application. Water Quality Technical Report. <https://www.aucklandcouncil.govt.nz/ResourceConsentDocuments/BUN60369079%20Water%20Quality%20Ass.pdf>
- Lacoste, É., McKindsey, C.W., Archambault, P. (2020) Biodiversity–Ecosystem Functioning (BEF) approach to further understanding aquaculture–environment interactions with application to bivalve culture and benthic ecosystems. *Reviews in Aquaculture*, 12(4): 2027-2041. <https://doi.org/10.1111/raq.12420>
- Lane, H.S., Brosnahan, C.L., Poulin, R. (2022) Aquatic disease in New Zealand: synthesis and future directions. *New Zealand Journal of Marine and Freshwater Research*, 56(1): 1-42. <https://doi.org/10.1080/00288330.2020.1848887>
- Langhamer, O., Haikonen, K., Sundberg, J. (2010) Wave power—Sustainable energy or environmentally costly? A review with special emphasis on linear wave energy converters. *Renewable and Sustainable Energy Reviews*, 14(4): 1329-1335. <https://doi.org/10.1016/j.rser.2009.11.016>
- Leng, Q., Mohamat-Yusuff, F., Mohamed, K.N., Zainordin, N.S., Hassan, M.Z. (2024) Impacts of thermal and cold discharge from power plants on marine benthos and its mitigation measures: a systematic review. *Frontiers in Marine Science*, 11. <https://doi.org/10.3389/fmars.2024.1465289>
- Levin, L.A., Mengerink, K., Gjerde, K.M., Rowden, A.A., Van Dover, C.L., Clark, M.R., Ramirez-Llodra, E., Currie, B., Smith, C.R., Sato, K.N., Gallo, N., Sweetman, A.K., Lily, H., Armstrong, C.W., Bridler, J. (2016) Defining “serious harm” to the marine environment in the context of deep-seabed mining. *Marine Policy*, 74: 245-259. <https://doi.org/10.1016/j.marpol.2016.09.032>
- Liu, Y., Huang, H., Yan, L., Liu, X., Zhang, Z. (2016) Influence of suspended kelp culture on seabed sediment composition in Heini Bay, China. *Estuarine, Coastal and Shelf Science*, 181: 39-50. <https://doi.org/10.1016/j.ecss.2016.07.017>
- Llabrés Pohl, I. (2023) The State of Shipping and Oceans. Understanding the impact of global shipping on climate, the ocean and human health. Consultancy report for Seas at Risk: 128. <https://seas-at-risk.org/wp-content/uploads/2023/07/The-State-of-Shipping-and-Oceans-Report-Final.pdf>
- Lloret, J., Turiel, A., Solé, J., Berdalet, E., Sabatés, A., Olivares, A., Gili, J.-M., Vila-Subirós, J., Sardá, R. (2022) Unravelling the ecological impacts of large-scale offshore wind farms in the Mediterranean Sea. *Science of the Total Environment*, 824: 153803. <https://doi.org/10.1016/j.scitotenv.2022.153803>
- Lloyd, B. (2003) Potential effects of mussel farming on New Zealand’s marine mammals and seabirds: a discussion paper. Department of Conservation: 34.

https://www.doc.govt.nz/globalassets/documents/science-and-technical/mussel_farms_marine_mammals_seabirds.pdf

Lull, T., Mujal-Colilles, A., Castells, M.I., Gironella, X. (2020) Composite methodology to prevent ship propeller erosion. *Ocean Engineering*, 195: 106751.

<https://doi.org/10.1016/j.oceaneng.2019.106751>

Lymperopoulou, D.S., Dobbs, F.C. (2017) Bacterial Diversity in Ships' Ballast Water, Ballast-Water Exchange, and Implications for Ship-Mediated Dispersal of Microorganisms. *Environmental Science & Technology*, 51(4): 1962-1972.

<https://doi.org/10.1021/acs.est.6b03108>

Lyttelton Port Company (2019a) 5.0 Erosion and sediment control. Construction Environmental Management Plan. <https://www.lpc.co.nz/wp-content/uploads/2020/05/LPC-Construction-Enviornmental-Management-Plan-FULL-DOCUMENT.pdf>

Lyttelton Port Company (2019b) 8.0 Wildlife. Construction Environmental Management Plan: 36. <https://www.lpc.co.nz/wp-content/uploads/2020/05/LPC-Construction-Enviornmental-Management-Plan-FULL-DOCUMENT.pdf>

MacDiarmid, A., Beaumont, J., Bostock, H., Bowden, D., Clark, M., Hadfield, M., Heath, P., Lamarche, G., Nodder, S., Orpin, A., Stevens, C., Thompson, D., Torres, L., Wysoczansk, R. (2011) Expert Risk Assessment of Activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf. NIWA Client Report, WLG2011-39: 140.

<https://environment.govt.nz/assets/publications/Files/niwa-risk-assessment-2012.pdf>

Macdiarmid, A., McKenzie, A., Sturman, J., Beaumont, J., Mikaloff-Fletcher, S., Dunne, J. (2012) Assessment of anthropogenic threats to New Zealand marine habitats. *New Zealand Aquatic Environment and Biodiversity Report*, No. 93: 255.

MacLeod, I.D. (2016) In-situ Corrosion Measurements of WWII Shipwrecks in Chuuk Lagoon, Quantification of Decay Mechanisms and Rates of Deterioration. *Frontiers in Marine Science*, 3. <https://doi.org/10.3389/fmars.2016.00038>

Majcher, J., Quinn, R., Plets, R., Coughlan, M., McGonigle, C., Sacchetti, F., Westley, K. (2021) Spatial and temporal variability in geomorphic change at tidally influenced shipwreck sites: The use of time-lapse multibeam data for the assessment of site formation processes. *Geoarchaeology*, 36(3): 429-454.

<https://doi.org/10.1002/gea.21840>

Malcolm Hunt Associates (2020) Assessment of Environmental Noise Effects. Maintenance Dredging and Disposal Project Port Navigation Channel, Vessel Turning Basin & Wharves 4-8 Eastland Port, Gisborne: 22.

https://www.gdc.govt.nz/_data/assets/pdf_file/0022/30469/Appendix-N-Hunt-and-Associates-Ltd-Noise-Assessment-Report.pdf

Martínez-Curci, N.S., Fierro, P., Navedo, J.G. (2023) Does experimental seaweed cultivation affect benthic communities and shorebirds? Applications for extensive aquaculture. *Ecological Applications*, 33(3): e2799. <https://doi.org/10.1002/eap.2799>

<https://doi.org/10.1002/eap.2799>

- McClellan, R. (2017) Potential effects on birds of a proposed new wharf and dredging project at the Port of Napier. Wildlands Contract Report, No. 4247: 36. <https://www.hbrc.govt.nz/assets/Document-Library/Consents/Port-of-Napier/Vol-3/Appendix-L-4247-Napier-Port-wharf-construction-effects-FINAL.pdf>
- McClellan, R., Reid, A., Pyatt, T. (2020) Foveaux Strait Seabirds: Assessment Of Environmental Effects For Project South. Wildlands Consultants Contract Report, No. 5155a. <https://www.sanford.co.nz/assets/Appendix-I.pdf>
- McLeod, R.J., Wing, S.R. (2008) Influence of an altered salinity regime on the population structure of two infaunal bivalve species. *Estuarine, Coastal and Shelf Science*, 78(3): 529-540. <https://doi.org/10.1016/j.ecss.2008.01.019>
- McPherson, C., Li, Z., Quijano, J. (2019) Underwater sound propagation modelling to illustrate potential noise exposure to Maui dolphins from seismic surveys and vessel traffic on West Coast North Island, New Zealand. . New Zealand Aquatic Environment and Biodiversity Report No. 217. <https://www.mpi.govt.nz/dmsdocument/35013-AEBR-217-Underwater-sound-propagation-modelling-to-illustrate-potential-noise-exposure-to-Maui-dolphins-from-seismic-surveys-and-vessel-traffic-on-West-Coast-North-Island-New-Zealand>
- Mendoza, E., Lithgow, D., Flores, P., Felix, A., Simas, T., Silva, R. (2019) A framework to evaluate the environmental impact of OCEAN energy devices. *Renewable and Sustainable Energy Reviews*, 112: 440-449. <https://doi.org/10.1016/j.rser.2019.05.060>
- Michel, J., A.C. Bejarano, C.H. Peterson, and C. Voss (2013) Review of Biological and Biophysical Impacts from Dredging and Handling of Offshore Sand. U.S. Department of the Interior, Bureau of Ocean Energy Management, Herndon, VA. OCS Study BOEM 2013-0119: 258. <https://espis.boem.gov/final%20reports/5268.pdf>
- Miller, R.G., Hutchison, Z.L., Macleod, A.K., Burrows, M.T., Cook, E.J., Last, K.S., Wilson, B. (2013) Marine renewable energy development: assessing the Benthic Footprint at multiple scales. *Frontiers in Ecology and the Environment*, 11(8): 433-440. <https://doi.org/10.1890/120089>
- Ministry for Primary Industries (2013a) Literature Review of ecological effects of aquaculture: Chapter 1. <https://www.mpi.govt.nz/dmsdocument/3749-Literature-Review-of-Ecological-Effects-of-Aquaculture-Chapter-1-Introduction>
- Ministry for Primary Industries (2013b) Overview of ecological effects of aquaculture: 79. <https://www.mpi.govt.nz/dmsdocument/4300-Overview-of-ecological-effects-of-Aquaculture>
- Ministry for the Environment (2005) Offshore Options: Managing Environmental Effects in New Zealand's Exclusive Economic Zone, ME number: 603: 57. <https://www.environment.govt.nz/assets/Publications/Files/offshore-options-jun05.pdf>
- Miralles, L., Ibabe, A., González, M., García-Vázquez, E., Borrell, Y.J. (2021) "If You Know the Enemy and Know Yourself": Addressing the Problem of Biological Invasions in Ports Through a New NIS Invasion Threat Score, Routine Monitoring, and Preventive Action Plans. *Frontiers in Marine Science*, 8. <https://doi.org/10.3389/fmars.2021.633118>

- Miró, J.M., Megina, C., Donázar-Aramendía, I., García-Gómez, J.C. (2022) Effects of maintenance dredging on the macrofauna of the water column in a turbid estuary. *Science of the Total Environment*, 806: 151304. <https://doi.org/10.1016/j.scitotenv.2021.151304>
- Missimer, T.M., Maliva, R.G. (2018) Environmental issues in seawater reverse osmosis desalination: Intakes and outfalls. *Desalination*, 434: 198-215. <https://doi.org/10.1016/j.desal.2017.07.012>
- Morrisey, D., Cameron, M., Newcombe, E. (2018) Effects of moorings on different types of marine habitat. Cawthron Report, No. 3098: 41. <https://www.envirolink.govt.nz/assets/Envirolink/Reports/1815-MLDC137-Effects-of-moorings-on-different-types-of-marine-habitats.pdf>
- Morrisey, D.J., Gibbs, M.M., Pickmere, S.E., Cole, R.G. (2000) Predicting impacts and recovery of marine-farm sites in Stewart Island, New Zealand, from the Findlay–Watling model. *Aquaculture*, 185(3): 257-271. [https://doi.org/10.1016/S0044-8486\(99\)00360-9](https://doi.org/10.1016/S0044-8486(99)00360-9)
- Navedo, J.G., Verdugo, C., Rodríguez-Jorquera, I.A., Abad-Gómez, J.M., Suazo, C.G., Castañeda, L.E., Araya, V., Ruiz, J., Gutiérrez, J.S. (2019) Assessing the effects of human activities on the foraging opportunities of migratory shorebirds in Austral high-latitude bays. *PLoS One*, 14(3): e0212441. <https://doi.org/10.1371/journal.pone.0212441>
- Newell, R., Seiderer, L., Hitchcock, D. (1998) The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and marine biology*. CRC Press: 127-178.
- Nylund, A.T., Arneborg, L., Tengberg, A., Mallast, U., Hassellöv, I.M. (2021) In situ observations of turbulent ship wakes and their spatiotemporal extent. *Ocean Sci.*, 17(5): 1285-1302. <https://doi.org/10.5194/os-17-1285-2021>
- OECD (2010) *Advancing the Aquaculture Agenda: Workshop Proceedings*.
- Oldman, J., Lundquist, C., Cryer, M. (2005) Shellfish dispersal characteristics within Bream Bay and Whangarei Harbour. NIWA Client Report, HAM2005-035: 33.
- One Ocean Foundation (2024) *Ocean Disclosure Initiative: Ports and Warehousing Industry*. McKinsey & Company: 20. https://cdn.prod.website-files.com/622f5dc681e480028f7fc611/6613b6f5a338c00c9aadcd38_ODI%20Ports%20and%20Warehouses%20Industry%20Review.pdf
- OSPAR Commission (2009) *Assessment of the environmental impacts of cables - Biodiversity Series*, Publication Number: 437/2009: 19p. https://qsr2010.ospar.org/media/assessments/p00437_Cables.pdf
- Ozkan, C., Perez, K., Mayo, T. (2020) The impacts of wave energy conversion on coastal morphodynamics. *Science of the Total Environment*, 712: 136424. <https://doi.org/10.1016/j.scitotenv.2019.136424>
- Ozturk, D., Maras, E.E. (2024) Investigation of the effects of small fishing ports on the shoreline: a case study of Samsun, Turkey. *Journal of Coastal Conservation*, 28(1): 20. <https://doi.org/10.1007/s11852-023-01012-3>

- Panagopoulos, A., Haralambous, K.-J. (2020) Environmental impacts of desalination and brine treatment - Challenges and mitigation measures. *Marine Pollution Bulletin*, 161: 111773. <https://doi.org/10.1016/j.marpolbul.2020.111773>
- Paskyabi, M.B. (2015) Offshore Wind Farm Wake Effect on Stratification and Coastal Upwelling. *Energy Procedia*, 80: 131-140. <https://doi.org/10.1016/j.egypro.2015.11.415>
- Paxton, A.B., McGonigle, C., Damour, M., Holly, G., Caporaso, A., Campbell, P.B., Meyer-Kaiser, K.S., Hamdan, L.J., Mires, C.H., Taylor, J.C. (2023) Shipwreck ecology: Understanding the function and processes from microbes to megafauna. *Bioscience*, 74(1): 12-24. <https://doi.org/10.1093/biosci/biad084>
- Paxton, A.B., Riley, T.N., Steenrod, C.L., Puckett, B.J., Alemu I, J.B., Paliotti, S.T., Adler, A.M., Exar, L., McLean, J.E.T., Kelley, J., Zhang, Y.S., Smith, C.S., Gittman, R.K., Silliman, B.R. (2024) Evidence on the performance of nature-based solutions interventions for coastal protection in biogenic, shallow ecosystems: a systematic map. *Environmental Evidence*, 13(1): 28. <https://doi.org/10.1186/s13750-024-00350-5>
- Paxton, A.B., Taylor, J.C., Nowacek, D.P., Dale, J., Cole, E., Voss, C.M., Peterson, C.H. (2017) Seismic survey noise disrupted fish use of a temperate reef. *Marine Policy*, 78: 68-73. <https://doi.org/10.1016/j.marpol.2016.12.017>
- Pine, M.K., Wilson, L., Jeffs, A.G., McWhinnie, L., Juanes, F., Scuderi, A., Radford, C.A. (2021) A Gulf in lockdown: How an enforced ban on recreational vessels increased dolphin and fish communication ranges. *Global Change Biology*, 27(19): 4839-4848. <https://doi.org/10.1111/gcb.15798>
- Pinkerton, M.H., Gall, M., Wood, S., Zeldis, J.R. (2018) Measuring the effects of bivalve mariculture on water quality in northern New Zealand using 15 years of MODIS-Aqua satellite observations. *Aquaculture Environment Interactions*, 10: 529-545.
- Plew, D.R. (2011) Depth-Averaged Drag Coefficient for Modeling Flow through Suspended Canopies. *Journal of Hydraulic Engineering*, 137(2): 234-247. [https://doi.org/10.1061/\(ASCE\)HY.1943-7900.0000300](https://doi.org/10.1061/(ASCE)HY.1943-7900.0000300)
- Plew, D.R. (2019) Investigating benthic impacts at salmon farms using eddy covariance measurements of benthic oxygen fluxes. *Aquaculture Environment Interactions*, 11: 337-357. <https://www.jstor.org/stable/26920848>
- Plew, D.R., Stevens, C.L. (2013) Numerical modelling of the effect of turbines on currents in a tidal channel – Tory Channel, New Zealand. *Renewable Energy*, 57: 269-282. <https://doi.org/10.1016/j.renene.2013.02.001>
- Powlesland, R.G. (2009) Impacts of wind farms on birds: a review. *Science for Conservation*, 289. <https://www.doc.govt.nz/documents/science-and-technical/sfc289entire.pdf>
- Poynter, M. (2020) Gisborne Port: Maintenance Dredging & Associated Disposal Of Dredged Material Port Navigation Channel, Vessel Turning Basin and Wharves 4-8. Prepared by 4Sight Consulting for Eastland Port: 100. https://www.gdc.govt.nz/_data/assets/pdf_file/0021/30468/Appendix-M-4Sight-Ecology-and-Water-Quality-Report.pdf

- Putland, R.L., Merchant, N.D., Farcas, A., Radford, C.A. (2018) Vessel noise cuts down communication space for vocalizing fish and marine mammals. *Global Change Biology*, 24(4): 1708-1721. <https://doi.org/10.1111/gcb.13996>
- Ramirez-Llodra, E., De Mol, B., Company, J.B., Coll, M., Sardà, F. (2013) Effects of natural and anthropogenic processes in the distribution of marine litter in the deep Mediterranean Sea. *Progress in Oceanography*, 118: 273-287. <https://doi.org/10.1016/j.pocean.2013.07.027>
- Rezaei, T., Javadi, A. (2024) Environmental impact assessment of ocean energy converters using quantum machine learning. *J Environ Manage*, 362: 121275. <https://doi.org/10.1016/j.jenvman.2024.121275>
- Richardson, W.J., Würsig, B. (1997) Influences of man-made noise and other human actions on cetacean behaviour. *Marine and Freshwater Behaviour and Physiology*, 29(1-4): 183-209. <https://doi.org/10.1080/10236249709379006>
- Roberts, D.A. (2012) Causes and ecological effects of resuspended contaminated sediments (RCS) in marine environments. *Environment International*, 40: 230-243. <https://doi.org/10.1016/j.envint.2011.11.013>
- Roberts, J. (2017) Review of potential NZ sea lion interactions with aquaculture at Port Pegasus/Pikihati. NIWA Client Report, 2017264WN: 36. <https://www.mpi.govt.nz/dmsdocument/23011-Review-of-potential-NZ-sea-lion-interactions-with-aquaculture-at-Port-PegasusPikihati>
- Rogers, C.S., Garrison, V.H. (2001) Ten years after the crime: Lasting effects of damage from a cruise ship anchor on a coral reef in St. John, U.S. Virgin Islands. *Bulletin of Marine Science*, 69(2): 793-803. <https://www.ingentaconnect.com/content/umrsmas/bullmar/2001/00000069/00000002/art00043>
- Roncolato, F., Fellowes, T.E., Duce, S., Mora, C., Johansson, O., Strachan, I., Bugnot, A.B., Erickson, K., Figueira, W., Gribben, P.E., Pine, C., Morgan, B., Vila-Concejo, A. (2024) Ecomorphodynamics of oyster reefs and their influence on oyster reef morphology. *Geomorphology*, 456: 109213. <https://doi.org/10.1016/j.geomorph.2024.109213>
- Ross, P.M., Battershill, C.N., Loomb, C. (2016) The wreck of the MV Rena: spatio-temporal analysis of ship-derived contaminants in the sediments and fauna of Astrolabe Reef. *New Zealand Journal of Marine and Freshwater Research*, 50(1): 87-114. <https://doi.org/10.1080/00288330.2015.1077873>
- Rowden, A., Leduc, D., Torres, L., Bowden, D., Hart, A., Chin, C., Davey, N., Wright, J., Carter, M., Crocker, B., Halliday, J., Loerz, A.-N., Read, G., Mills, S., Anderson, O., Neill, K., Kelly, M., Tracey, D., Kaiser, S., Gordon, D., Wilkins, S., Horn, P., Pallentin, A., Nodder, S., Mackay, K., Northcote, L. (2013) Benthic communities of MPL area 50270 on the Chatham Rise. Prepared for Chatham Rock Phosphate Ltd. NIWA Client Report, WLG2012-25: 102. <https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000006/Applicants-proposal-documents/e8784b016d/EEZ000006-Appendix15-Rowden-et-al-Benthic-Communities-Report.pdf>

- Rutger, S., Wing, S. (2006) Effects of freshwater input on shallow-water infaunal communities in Doubtful Sound, New Zealand. *Marine Ecology Progress Series*, 314: 35-47. <https://www.int-res.com/articles/meps2006/314/m314p035.pdf>
- Sá, S., Bastos-Santos, J., Araújo, H., Ferreira, M., Duro, V., Alves, F., Panta-Ferreira, B., Nicolau, L., Eira, C., Vingada, J. (2016) Spatial distribution of floating marine debris in offshore continental Portuguese waters. *Marine Pollution Bulletin*, 104(1): 269-278. <https://doi.org/10.1016/j.marpolbul.2016.01.011>
- Salleh, N.A., Rosli, F.N., Akbar, M.A., Yusof, A., Sahrani, F.K., Razak, S.A., Ahmad, A., Usup, G., Bunawan, H. (2021) Pathogenic hitchhiker diversity on international ships' ballast water at West Malaysia port. *Marine Pollution Bulletin*, 172: 112850. <https://doi.org/10.1016/j.marpolbul.2021.112850>
- Schaffelke, B., Smith, J.E., Hewitt, C.L. (2006) Introduced Macroalgae – a Growing Concern. *Journal of Applied Phycology*, 18(3): 529-541. <https://doi.org/10.1007/s10811-006-9074-2>
- Schiel, D.R., Ross, P.M., Battershill, C.N. (2016) Environmental effects of the MV Rena shipwreck: cross-disciplinary investigations of oil and debris impacts on a coastal ecosystem. *New Zealand Journal of Marine and Freshwater Research*, 50(1): 1-9. <https://doi.org/10.1080/00288330.2015.1133665>
- Sea, M.A., Hillman, J.R., Thrush, S.F. (2022) The influence of mussel restoration on coastal carbon cycling. *Global Change Biology*, 28(17): 5269-5282. <https://doi.org/10.1111/gcb.16287>
- Serrano, O., Ruhon, R., Lavery, P.S., Kendrick, G.A., Hickey, S., Masqué, P., Arias-Ortiz, A., Steven, A., Duarte, C.M. (2016) Impact of mooring activities on carbon stocks in seagrass meadows. *Scientific Reports*, 6(1): 23193. <https://doi.org/10.1038/srep23193>
- Sim-Smith, C., Lee, S., Daniel, S. (2023) Impacts of seabed disturbance in the Waikato region. Waikato Regional Council Technical Report, 2023/04. <https://www.waikatoregion.govt.nz/assets/WRC/TR202304.pdf>
- Široka, M., Piličić, S., Milošević, T., Lacalle, I., Traven, L. (2021) A novel approach for assessing the ports' environmental impacts in real time – The IoT based port environmental index. *Ecological Indicators*, 120: 106949. <https://doi.org/10.1016/j.ecolind.2020.106949>
- Smith, M., Inglis, G.J., Wilkens, S., McDonald, S. (2016) Emergency surveillance for marine pests after the grounding of the container vessel, MV Rena. *New Zealand Journal of Marine and Freshwater Research*, 50(1): 42-55. <https://doi.org/10.1080/00288330.2015.1127828>
- Sneddon, R., Atalah, J., Forrest, B., Mackenzie, L., Floerl, O. (2016) Assessment of impacts to benthic ecology and marine ecological resources from the proposed Lyttelton Harbour Channel Deepening Project. Prepared for Lyttelton Port Co Ltd. Cawthron Report, No. 2860a: 190. <https://www.lpc.co.nz/wp-content/uploads/2016/10/Appendix-15A.pdf>

- Sprovieri, M., Feo, M.L., Prevedello, L., Manta, D.S., Sammartino, S., Tamburrino, S., Marsella, E. (2007) Heavy metals, polycyclic aromatic hydrocarbons and polychlorinated biphenyls in surface sediments of the Naples harbour (southern Italy). *Chemosphere*, 67(5): 998-1009. <https://doi.org/10.1016/j.chemosphere.2006.10.055>
- Stanton, B., Pickard, G. (1980) *Physical Oceanography of the New Zealand Fiords*. New Zealand Oceanographic Institute Memoir: 37. https://webstatic.niwa.co.nz/library/Memoir%20088_Physical%20Oceanography%20of%20the%20New%20Zealand%20Fiords.pdf
- Su, S.H., Pearlman, L.C., Rothrock, J.A., Iannuzzi, T.J., Finley, B.L. (2002) Potential Long-Term Ecological Impacts Caused by Disturbance of Contaminated Sediments: A Case Study. *Environmental Management*, 29(2): 234-249. <https://doi.org/10.1007/s00267-001-0005-3>
- Sundberg, H., Hanson, M., Liewenborg, B., Zebühr, Y., Broman, D., Balk, L. (2007) Dredging associated effects: maternally transferred pollutants and DNA adducts in feral fish. *Environ Sci Technol*, 41(8): 2972-2977. <https://doi.org/10.1021/es070073j>
- Sustainable Business Network (2020) *Tackling plastic waste in New Zealand aquaculture* <https://www.mpi.govt.nz/dmsdocument/41121-Tackling-plastic-waste-in-NZ-aquaculture-FINAL-Full-Report>
- Suzdaleva, A.L., Beznosov, V.N. (2021) Artificial Reef: Status, Life Cycle, and Environmental Impact Assessment. *Power Technology and Engineering*, 55(4): 558-561. <https://doi.org/10.1007/s10749-021-01397-x>
- Tamburini, M., Keppel, E., Marchini, A., Repetto, M.F., Ruiz, G.M., Ferrario, J., Occhipinti-Ambrogi, A. (2021) Monitoring Non-indigenous Species in Port Habitats: First Application of a Standardized North American Protocol in the Mediterranean Sea. *Frontiers in Marine Science*, 8. <https://doi.org/10.3389/fmars.2021.700730>
- Taormina, B., Bald, J., Want, A., Thouzeau, G., Lejart, M., Desroy, N., Carlier, A. (2018) A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. *Renewable and Sustainable Energy Reviews*, 96: 380-391. <https://doi.org/10.1016/j.rser.2018.07.026>
- Taranaki Regional Council (2023) *Port Taranki Ltd. Maintenance Dredging Monitoring Programme Biennial Report 2020-2022*. Technical Report, 2022-75: 53. <https://www.trc.govt.nz/assets/Documents/Environment/Monitoring-Industry/2022/22-75-Port-Taranaki-Ltd-Maintenance-Dredging-Monitoring-Programme-Biennial-Report-2020-2022-3089361.PDF>
- Thompson, D. (2013) *Effects of ships lights on fish, squid and seabirds*. NIWA Client Report, WLG2013-16: 15. <https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000004/Applicants-proposal-documents/Ofc5f83116/EEZ000004-Effects-of-ships-lights-on-fish-squid-and-seabirds-NIWA-April-2013.pdf>

- Tonkin & Taylor Ltd. (2016) LPC Channel Deepening Project Review and summary of coastal process effects. Prepared for Lyttleton Port Company, 31791.v2: 38.
<https://www.lpc.co.nz/wp-content/uploads/2016/06/Appendix-7.pdf>
- United Nations Environment Programme Finance Initiative (2022) Harmful Marine Extractives: Understanding the risks & impacts of financing non-renewable extractive industries., <https://www.unepfi.org/publications/harmful-marine-extractives-dredging-marine-aggregate-extraction/#:~:text=Dredging%20and%20marine%20aggregate%20extraction,and%20deep%20sea%20mining%20sectors>.
- van der Molen, J., Smith, H.C.M., Lepper, P., Limpenny, S., Rees, J. (2014) Predicting the large-scale consequences of offshore wind turbine array development on a North Sea ecosystem. *Continental Shelf Research*, 85: 60-72.
<https://doi.org/10.1016/j.csr.2014.05.018>
- Van Dover, C.L. (2014) Impacts of anthropogenic disturbances at deep-sea hydrothermal vent ecosystems: A review. *Marine Environmental Research*, 102: 59-72.
<https://doi.org/10.1016/j.marenvres.2014.03.008>
- van Katwijk, M.M., Bos, A.R., Hermus, D.C.R., Suykerbuyk, W. (2010) Sediment modification by seagrass beds: Muddification and sandification induced by plant cover and environmental conditions. *Estuarine, Coastal and Shelf Science*, 89(2): 175-181.
<https://doi.org/10.1016/j.ecss.2010.06.008>
- Walker, T.R., Adebambo, O., Del Aguila Feijoo, M.C., Elhaimer, E., Hossain, T., Edwards, S.J., Morrison, C.E., Romo, J., Sharma, N., Taylor, S., Zomorodi, S. (2019) Chapter 27 - Environmental Effects of Marine Transportation. In: C. Sheppard (Ed). *World Seas: An Environmental Evaluation (Second Edition)*. Academic Press: 505-530.
<https://doi.org/10.1016/B978-0-12-805052-1.00030-9>
- Walls, A.M., Kennedy, R., Edwards, M.D., Johnson, M.P. (2017) Impact of kelp cultivation on the Ecological Status of benthic habitats and *Zostera marina* seagrass biomass. *Marine Pollution Bulletin*, 123(1): 19-27. <https://doi.org/10.1016/j.marpolbul.2017.07.048>
- Wang, T., Ru, X., Deng, B., Zhang, C., Wang, X., Yang, B., Zhang, L. (2023) Evidence that offshore wind farms might affect marine sediment quality and microbial communities. *Science of the Total Environment*, 856: 158782.
<https://doi.org/10.1016/j.scitotenv.2022.158782>
- Want, A., Waldman, S., Burrows, M.T., Side, J.C., Venugopal, V., Bell, M.C. (2024) Predicted ecological consequences of wave energy extraction and climate-related changes in wave exposure on rocky shore communities. *ICES Journal of Marine Science*, 81(7): 1263-1281. <https://doi.org/10.1093/icesjms/fsae086>
- Ward, G.M., Faisan Jr, J.P., Cottier-Cook, E.J., Gachon, C., Hurtado, A.Q., Lim, P.E., Matoju, I., Msuya, F.E., Bass, D., Brodie, J. (2020) A review of reported seaweed diseases and pests in aquaculture in Asia. *Journal of the World Aquaculture Society*, 51(4): 815-828.
<https://doi.org/10.1111/jwas.12649>

- Watson-Capps, J.J., Mann, J. (2005) The effects of aquaculture on bottlenose dolphin (*Tursiops* sp.) ranging in Shark Bay, Western Australia. *Biological Conservation*, 124(4): 519-526. <https://doi.org/10.1016/j.biocon.2005.03.001>
- Watson, S.J., Neil, H., Ribó, M., Lamarche, G., Strachan, L.J., MacKay, K., Wilcox, S., Kane, T., Orpin, A., Nodder, S., Pallentin, A., Steinmetz, T. (2020) What We Do in the Shallows: Natural and Anthropogenic Seafloor Geomorphologies in a Drowned River Valley, New Zealand. *Frontiers in Marine Science*, 7. <https://doi.org/10.3389/fmars.2020.579626>
- Watson, S.J., Ribó, M., Seabrook, S., Strachan, L.J., Hale, R., Lamarche, G. (2022) The footprint of ship anchoring on the seafloor. *Scientific Reports*, 12(1): 7500. <https://doi.org/10.1038/s41598-022-11627-5>
- Williamson, P., Wallace, D.W.R., Law, C.S., Boyd, P.W., Collos, Y., Croot, P., Denman, K., Riebesell, U., Takeda, S., Vivian, C. (2012) Ocean fertilization for geoengineering: A review of effectiveness, environmental impacts and emerging governance. *Process Safety and Environmental Protection*, 90(6): 475-488. <https://doi.org/10.1016/j.psep.2012.10.007>
- Wilson, B., Batty, R.S., Daunt, F., Carter, C. (2006) Collision risks between marine renewable energy devices and mammals, fish and diving birds. Report to the Scottish Executive. Scottish Association for Marine Science, PA37 1QA: 105. <https://nora.nerc.ac.uk/id/eprint/504110/1/N504110CR.pdf>
- Wong, K.L.C., O'Shea, S. (2011) The effects of a mussel farm on benthic macrofaunal communities in Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 45(2): 187-212. <https://doi.org/10.1080/00288330.2010.550628>
- Work, T.M., Aeby, G.S., Neal, B.P., Price, N.N., Conklin, E., Pollock, A. (2018) Managing an invasive corallimorph at Palmyra Atoll National Wildlife Refuge, Line Islands, Central Pacific. *Biological Invasions*, 20(8): 2197-2208. <https://doi.org/10.1007/s10530-018-1696-1>
- Xiao, X., Agustí, S., Yu, Y., Huang, Y., Chen, W., Hu, J., Li, C., Li, K., Wei, F., Lu, Y., Xu, C., Chen, Z., Liu, S., Zeng, J., Wu, J., Duarte, C.M. (2021) Seaweed farms provide refugia from ocean acidification. *Science of the Total Environment*, 776: 145192. <https://doi.org/10.1016/j.scitotenv.2021.145192>
- Ytreberg, E., Eriksson, M., Maljutenko, I., Jalkanen, J.-P., Johansson, L., Hassellöv, I.-M., Granhag, L. (2020) Environmental impacts of grey water discharge from ships in the Baltic Sea. *Marine Pollution Bulletin*, 152: 110891. <https://doi.org/10.1016/j.marpolbul.2020.110891>
- Yudhistira, M.H., Karimah, I.D., Maghfira, N.R. (2022) The effect of port development on coastal water quality: Evidence of eutrophication states in Indonesia. *Ecological Economics*, 196: 107415. <https://doi.org/10.1016/j.ecolecon.2022.107415>
- Zhuang, Y., Li, Y., Su, W. (2016) Influence of Anchoring on Burial Depth of Submarine Pipelines. *PLoS One*, 11(5): e0154954. <https://doi.org/10.1371/journal.pone.0154954>