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Colonisation of a Newly Deployed Artificial Reef Vessel Within a Marine Protected Area in the Eastern Mediterranean: Establishing a Baseline for Long-Term Ecological Monitoring

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Abstract

Artificial reefs (ARs) can provide structurally complex habitats that support the development of benthic and fish communities, but their ecological development remains poorly documented in Cyprus. This study provides the first biological assessment of the AR vessel Lambousa II approximately one year after deployment within the Boroklini–Larnaka Marine Protected Area (MPA). Fish assemblages were assessed using underwater visual census, timed visual searches and baited remote underwater video, while benthic communities were investigated using photoquadrats and brush sampling. The vessel supported 13 fish species, comprising six native and seven non-indigenous, with marked differences in abundance and composition among vessel sections. Benthic surveys identified 11 biological taxa in photoquadrats and 18 taxa through brush sampling, with a pronounced spatial variation in community development. Five benthic species were classified as non-indigenous, including *Diala semistriata*, which represents the first recording for Cyprus. The occurrence of commercially important fish species and early life stages further indicates that the vessel may provide shelter and feeding opportunities. Overall, Lambousa II has rapidly developed a heterogeneous biological community within its first year, providing an important baseline for long-term monitoring of AR development and associated biodiversity.

Keywords: Levantine; fisheries reserve; shipwreck; non-indigenous species; *Diala semistriata*; ecological monitoring

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1. Introduction

Marine Protected Areas (MPAs) based on Framework Directive 2008/56/EC for the European Union's Marine Strategy and COM (2020), are geographically established spaces, managed through legal means, for the conservation of marine biodiversity, the enhancement of fishery sustainability, the protection of ecosystem functions, and the safeguarding of cultural heritage [1–6]. Parties to the Convention on Biological Diversity use MPAs as one of the measures to protect 30% of the ocean by 2030 [4]. Within the Eastern Mediterranean, a climate change hotspot, MPAs are further seen as integral management tools for combating climate change [3,4,7]. One of the main threats to biodiversity and the marine environments that MPAs, and especially no-take zones (NTZs), have shown to be beneficial

against is overfishing [2,4,8,9]. Within this framework, MPAs known as marine reserves are established as strict NTZs designed specifically as a mitigation measure against fishing pressure and the improvement of fishing stock [8–12]. This is directly linked to proper regulation, governance and enforcement [2,4,9]. Social acceptance by local communities and the integration of cultural perspective further reinforce MPA effectiveness [3,8,13]. Most importantly, once a population stock threshold is reached within an MPA, its positive effects are experienced by local fishermen and fisherwomen through the process known as spillover, where the MPA itself can no longer support the increasing fish populations and fish are forced to expand outside the borders of the MPA [4,8,14,15].

Artificial reefs (ARs) within MPA present an opportunity to accelerate ecological recovery, develop a robust sanctuary and boost fish stocks [8,16–18]. This is accomplished through the introduction of three-dimensional structurally complex, hard substrates in previously flat, barren or degraded marine habitats, thereby replicating the ecological functions and physical characteristics of natural reefs [16–21]. The artificial structures provide hard substrate for the settlement and colonisation of sessile benthic organisms, offer shelter, and serve as a nursery and breeding ground for many marine species [16,19–22]. Moreover, they support local food webs through improved benthic productivity and complex trophic interactions [16,19,22]. Newly submerged structures, such as deployed vessels, typically undergo a rapid colonisation during the first year of deployment by algae, sessile invertebrates, microbial communities and mobile fauna, later followed by a period of equilibrium through ecological succession tending to climax status [20,21].

The Boroklini MPA in Cyprus, an established marine reserve since 2019, covers an approximate area of 2.2 km^2 and is a highly heterogeneous coastal ecosystem situated within an urbanised environment [23]. In 2020, a Ministerial Decree (ΚΔΠ 124/2020) banned all fishing activities, commercial and recreational, within the MPA [23,24]. The protected area encompasses a mosaic of habitats, including shallow rocky reefs, *Posidonia oceanica* meadows and an extensive soft-sediment habitat, along with the diligent placement of three vessels as ARs [24,25]. Prior to the mass mortality of *Pinna nobilis* (Linnaeus, 1758), one of the largest bivalve species in the world and an important habitat-forming organism in Mediterranean coastal ecosystems, the species was widely distributed across the extensive soft-sediment habitats of the MPA [24,26]. Subsequently, the flourishing Pinna population along the soft-bottom sediment encouraged an abundance of *Octopus vulgaris* [27]. To encourage the enhancement of fish stocks within the MPA, two AR vessels, *ELPIDA* (cargo ship; length: 63 m, depth: 27 m) and LEF 1 (length: 15.5 m, depth: 13 m), were deployed in 2019 [23,24]. Additionally, the vessel Lambousa II, *a* 22 m-length tugboat, was submerged at a depth of 21 m on the 15th of February 2025 on a previously predominantly barren muddy seabed [23,24,28]. Cyprus is a contracting party to the Barcelona Convention under the United Nations Environment Programme Mediterranean Action Plan (UNEP/MAP), and therefore, each vessel before deployment underwent environmental preparation in accordance with the regional guidelines and criteria governing the deployment of artificial wrecks within the Mediterranean [29,30].

AR deployment in the Boroklini MPA is part of the broader management strategy aimed at enhancing local commercial ichthyofauna populations while simultaneously supporting local and touristic recreational diving activities across Cyprus [23,24]. Despite the significance of the area, no ecological monitoring programme has been conducted since its establishment, and therefore, the status of the biological communities within the area is unknown. Lambousa II's recent deployment provides a unique opportunity to investigate the initial stages of ecological succession, as well as track the biological development of the communities associated with artificial wrecks in an oligotrophic habitat, as the E. Mediterranean is exploited by waves of non-indigenous and invasive species.

The present study presents the first publication of AR ecological assessment within the Republic of Cyprus, with a focus centred on the recently submerged vessel Lambousa II in the MPA Boroklini–Larnaka. Specifically, the investigation characterises the benthic assemblage and fish community associated with the vessel, quantifies biological cover and fish abundance, and examines spatial variation in community composition among different vessel sections. We hypothesised that approximately one year after deployment (14 months), (i) the wreck would support an assemblage of early successional benthic organisms, (ii) the structural complexity of the vessel would support a diverse fish assemblage, and (iii) different sections of the vessel would exhibit distinct benthic and fish community composition.

2. Materials and Methods

2.1. Field Survey

A monitoring survey of the vessel Lambousa II (maximum depth: 21 m; length: 22 m; Lat: 34.962902°, Long: 33.686917°) in Cyprus was conducted in April 2026 by four scientific divers (two dives, t = 40 min each, visibility = 20 m, temp. at 21 m—sea floor: 18 °C temp. at 13 m—top of the mast: 19 °C, 14 months after deployment) working in teams of two. The survey consisted of a fish assessment using underwater visual census (UVC) and baited remote underwater video (BRUV), while benthic communities were assessed using photoquadrats and brush sampling. Upon completion of the quantitative survey, all four divers conducted a systematic visual census around the vessel to collect additional qualitative observations of conspicuous, rare, or cryptic species that may not have been detected during the standardised sampling. To ensure a representative classification of colonisation across the vessel, sampling locations for all techniques were pre-selected during an initial scouting dive (Figure 1).

2.2. Benthic Community Assessment

A total of 25 photoquadrats (20 × 20 cm) were collected across the vessel using an Olympus TG-7 camera (OM Digital Solutions Corporation, Hachioji, Japan) equipped with a SeaLife Seadragon light (Pioneer Research, Moorestown, NJ, USA). Sampling locations included four quadrats on both the port and starboard sides, four on the main deck, two on the beam, two inside the bridge, two inside the front of the vessel, two on the first level, one in the corridor leading to the steering room, and four within the engine room. Of these, three quadrats were located on the ceiling, one on the floor, and the remainder on the vertical surfaces of the vessel. To maintain a constant camera-to-quadrat distance, the quadrat was attached directly to the camera using a rigid PVC frame. Additional close-up (macro) photographs of the substrate were taken to facilitate the accurate identification and classification of the recorded organisms. Photographs were analysed using PhotoQuad (v1_4) to quantify benthic cover and community composition (points = 100 uniform).

In addition, seven brush samples were collected using the same 20 × 20 cm quadrat frame to characterise the benthic micro-organism communities associated with the vessel. Samples were collected from the corridor leading to the steering room (n = 1), the engine room (n = 1), the main deck (n = 2), the mast (n = 1), the port side (n = 1), and the first level (n = 1). Each brush sample was collected approximately 2 cm to the right of the corresponding photoquadrat to avoid disturbing the photographed surface while ensuring comparable sampling locations. The surface within each quadrat was brushed twice from left to right to ensure complete coverage of the sampled area and minimise the likelihood of micro-organisms remaining on the substrate. The collected material was initially placed in zip-lock bags and subsequently transferred to specimen containers containing absolute ethanol for preservation prior to further laboratory analysis. Identification was conducted

at the lowest possible taxonomic level using standard taxonomic identification keys, online databases, peer-reviewed literature, and taxonomic experts [31–45].

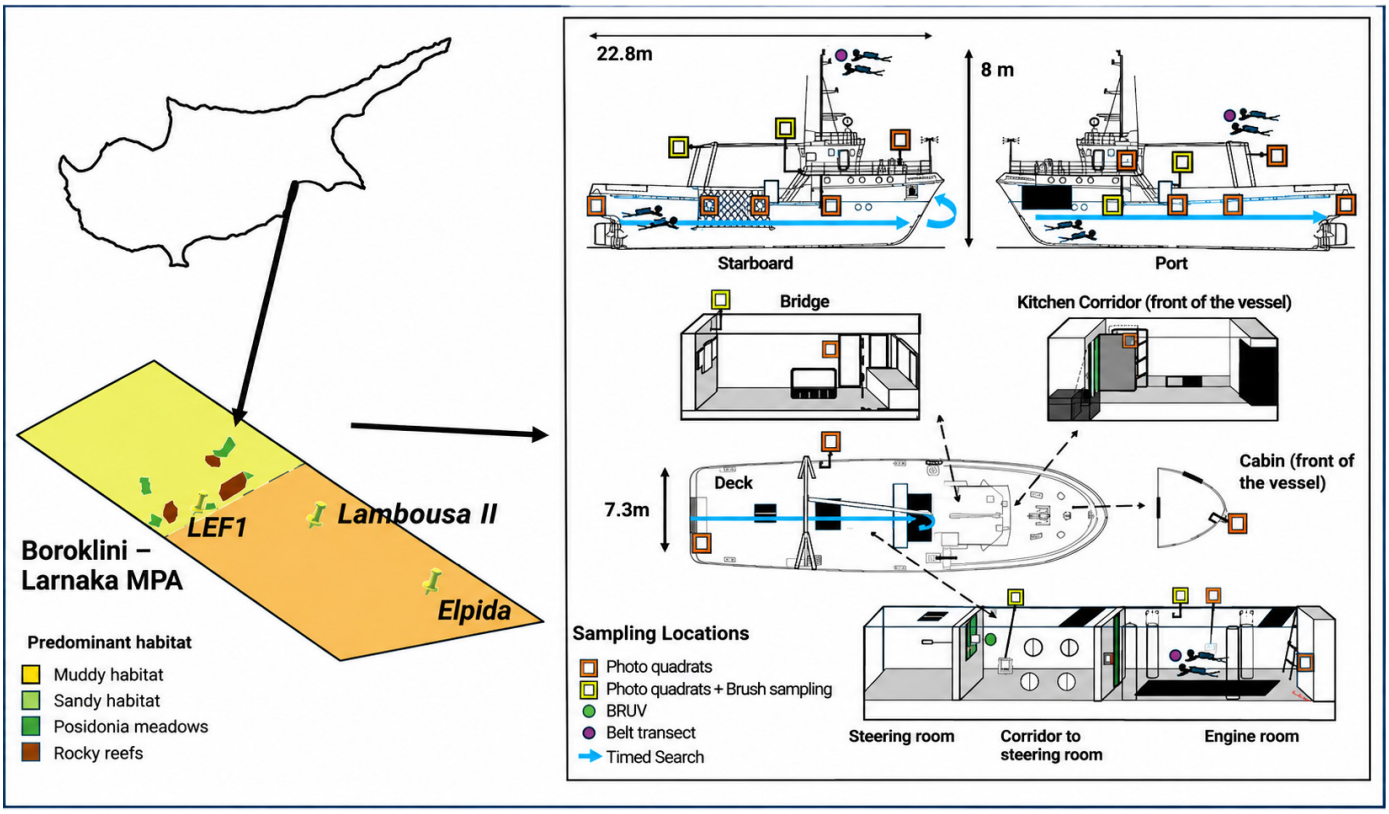

Figure 1. Illustration of the location of the Boroklini–Larnaka MPA, the predominant habitats characterising the location of Lambousa II, and a diagram of the vessel, along with the various sampling locations and techniques used during the first biological monitoring approximately one year after submergence [23,28].

2.3. Fish Assemblage Assessment

Visual belt transects (one per location) were conducted by a team of two scientific divers along both sides of the vessel (length = 23 m; width = 5 m; 10 min) and the main deck (length = 10 m; width = 5 m; 10 min). Due to the confined nature of the engine room and abundance of potential refuge habitats, fish assemblages were assessed by the same team using a timed visual search (3 min). During the engine room timed-search survey, all accessible cavities, crevices, and sheltered areas were systematically inspected using an underwater flashlight (Daskfire, Shenzhen, China). The same timed search period (3 min) was applied around the two prominent structural features of the vessel, the mast and beam, which represent the highest relief features.

Several areas of the vessel, including the steering room, are inaccessible to divers and provide semi-dark habitats. To assess fish assemblages within the steering room, one BRUV (GoPro Hero 3, GoPro, Inc., San Mate, CA, USA, wide angle—170° diagonal angle of view, resolution 2.7 K, frame rate 29.97 frames/sec, t = 40 min; bait: one-third of a can of tuna and two small sardines, distance of bait to the camera: 60 cm) with a blue flashlight (SeaLife Mini Fluoro, Pioneer Research, NJ, USA) was deployed. The combined application of underwater visual census, timed searches, BRUV, and qualitative diver observations provided a comprehensive assessment of the fish assemblages associated with the Lambousa II wreck.

All encountered fishes across the four survey methods were identified to the lowest possible taxonomic level, counted, and assigned to one of four total length categories: 0–5 cm, 5–10 cm, 10–15 cm, and >15 cm.

2.4. Statistics

All statistical analyses were conducted in R (R version 4.5.2 (31 October 2025 ucrt)). Data organisation and graphical visualisation were performed using the tidyverse package [46], while ecological diversity and community dissimilarity were calculated using the vegan package [47].

For the UVC datasets, observations recorded simultaneously by the two divers were treated as paired estimates of the same survey rather than as independent replicates. Records from different size classes of the same species were first summed for each observer and sampling section. When a species was recorded by one observer but not by the other, a value of zero was assigned to the corresponding observation of the second observer. The mean abundance of each species was subsequently calculated across the two observers. Fish assemblages within each surveyed section were characterised using total mean abundance, species richness, and Shannon diversity index [48]. The Shannon diversity index was calculated using the natural logarithm, as implemented by the diversity() function in the vegan package.

Fish size structure was examined using the four total-length categories applied during the UVC. Raw records containing more specific size ranges above 15 cm were combined within the >15 cm category. Fish abundance was summed across species for each observer, size category, survey method, and vessel section. Size-category abundance was then averaged between the two simultaneous observers. For each section surveyed, the proportional contribution of each size category was calculated as a percentage of the total mean fish abundance. Summed mean abundance and percentage composition were also calculated across all surveyed sections to provide an overall descriptive summary of fish size structure.

Species composition was expressed as the relative abundance of each species within each section and was visualised using heat maps. Differences in fish assemblage composition among the surveyed sections were described using Bray–Curtis dissimilarity [49]. Before calculating the dissimilarity matrix, mean abundance data were square root transformed to reduce the influence of highly abundant schooling species. Fish species were additionally classified according to their biogeographic status as native or non-indigenous species (NIS). The richness, mean abundance, and proportional abundance of each group were calculated for each surveyed section and sampling method. Owing to differences in sampling effort and spatial coverage, the results from the belt transects and timed visual searches were considered complementary and were not directly compared as equivalent estimates of fish abundance. Records obtained from the BRUV survey and the subsequent qualitative visual search were used to supplement the cumulative fish species inventory of the vessel. These observations were not included in quantitative abundance comparisons because their sampling procedures and detection probabilities differed from those of the standardised UVC surveys.

Photoquadrat data were analysed using the percentage cover recorded for each taxon or morphotype. Metal structure, rust, and water or background were retained when describing surface-cover composition but excluded from biological diversity and community-composition analyses. Biological richness, total biological cover, and the Shannon diversity index were calculated for each photoquadrat. Taxon frequency of occurrence and mean percentage cover were calculated across all 25 photoquadrats. Photoquadrats were grouped by vessel station: engine room, deck, starboard, port, beam, cabin, and bridge. Mean cover composition and the mean and standard deviation of biological richness, Shannon

diversity, and biological cover were calculated for each station. Quadrat-level values were also presented according to sampling order to illustrate fine-scale spatial variability across the vessel. Biological community composition was explored using two-dimensional non-metric multidimensional scaling (NMDS) based on Bray–Curtis dissimilarity calculated from square root-transformed biological percentage-cover data. Photoquadrats without biological cover were excluded. Ordination patterns were displayed by the vessel station and interpreted descriptively, without inferential comparisons.

3. Results

3.1. Fish Assemblage Composition

A total of 13 fish species were recorded across the two underwater visual-census methods and the BRUV, comprising six native and seven NIS. Ten species were recorded during the timed search and eleven during the line transects, with eight species detected by both methods. *Pempheris rhomboidea* and *Sargocentron rubrum* were recorded only during the timed search and BRUV, whereas *Seriola dumerili*, *Synodus saurus*, and *Trachinus radiatus* were recorded only during the line transects.

Fish assemblage composition varied among the surveyed sections (Figure 2). *Cheilodipterus novemstriatus* was the most abundant species overall and was recorded in four sections, with its greatest mean abundance occurring in the engine room and starboard. *Parupeneus forsskali* was recorded in five of the six sections and was the most widely distributed species. Other frequently recorded species included *Pterois miles* and *Torquigener flavimaculosus*, both of which are NIS and occurred in four sections.

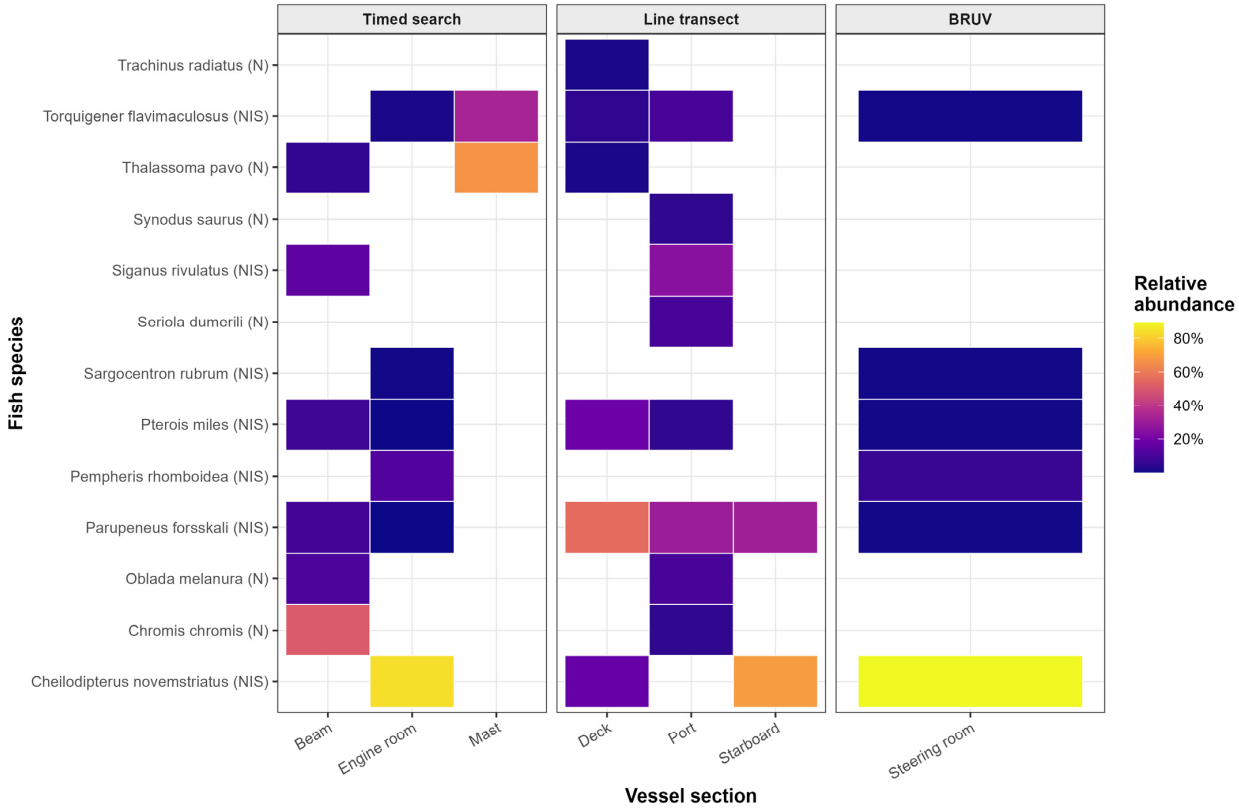

Figure 2. Relative fish species composition across the surveyed sections of Lambousa II, presented separately for the timed search, line transects and BRUV. Colour shows each species' proportion within each section. BRUV is excluded from the analysis. NIS classification: *Torquigener flavimaculosus* [50], *Siganus rivulatus* [51], *Sargocentron rubrum* [52], *Pterois miles* [53], *Pempheris rhomboidea* [54], *Parupeneus forsskali* [55], *Cheilodipterus novemstriatus* [56].

The BRUV survey recorded six species in the steering room, all of which were also detected by the UVC methods. A total number of 116 fishes were recorded over a period of 40 min, of which 89.7% were *Cheilodipterus novemstriatus*. During the timed search, total mean fish abundance ranged from 1.5 individuals at the mast to 119.0 individuals in the engine room. The engine-room assemblage contained six species and was dominated by *C. novemstriatus* (abundance = 84%), followed by *Pempheris rhomboidea* (12.6%). The beam contained six species, with the community dominated by the native species *Chromis chromis* (abundance = 51%). The mast had the lowest recorded abundance and richness, with two species and a Shannon diversity value of 0.64. Among the line-transect sections, the total mean abundance was greatest at the starboard side, with 72.5%, followed by the deck with 29.5%. Despite having the greatest abundance, the starboard contained only two species and had a Shannon diversity value of 0.62 (Table 1). Its assemblage comprised *C. novemstriatus* and *Parupeneus forsskali*, representing 69% and 31% of its total abundance, respectively. Species richness (n = 8 species) and Shannon diversity (H′ = 1.85) demonstrated their greatest values on the port side, whereas the beam had the highest Shannon diversity value (H′ = 1.45; Table 1) among the timed search sections.

Table 1. Summary of fish assemblage metrics and native: non-indigenous species (NIS) abundance across the surveyed sections of Lambousa II.

Survey Method	Wreck Section	Section Total Abundance	Species Richness	Shannon H′	Native Abundance (%)	NIS (%)
Timed search	Mast	3	2	0.64	66.7	33.3
Timed search	Engine room	238	6	0.56	0.0	100.0
Timed search	Beam	98	6	1.45	67.3	32.7
Line transect	Deck	59	6	1.23	3.4	96.6
Line transect	Starboard	145	2	0.62	0.0	100.0
Line transect	Port	20	8	1.85	30.0	70.0

Bray–Curtis dissimilarity (ordination stress = 0.045) indicated considerable variation in fish assemblage composition among the surveyed sections (Figure S1). The lowest dissimilarity was recorded between the deck and starboard (dissimilarity = 0.45), reflecting the occurrence and comparatively high abundance of *Cheilodipterus novemstriatus* and *Parupeneus forsskali* in both sections. The engine room and starboard also had relatively similar assemblages (dissimilarity = 0.47), largely because both were dominated by *C. novemstriatus*. The greatest dissimilarity was recorded between the mast and starboard (dissimilarity = 1.00), as these sections shared no recorded species. High dissimilarity was also observed between the mast and engine room (dissimilarity = 0.93) and between the engine room and beam (dissimilarity = 0.92). These values are descriptive and represent the baseline compositional differences recorded during the single survey.

3.2. Fish Size-Category Composition

The 0–5 cm size category dominated the fish observations, accounting for 61.8% of the summed mean abundance across all surveyed vessel sections. Fish measuring 5–10 cm represented 27.7% of the abundance, followed by the 10–15 cm category at 8%. Individuals larger than 15 cm were comparatively uncommon and accounted for 2.5% of the recorded abundance (Figure 3).

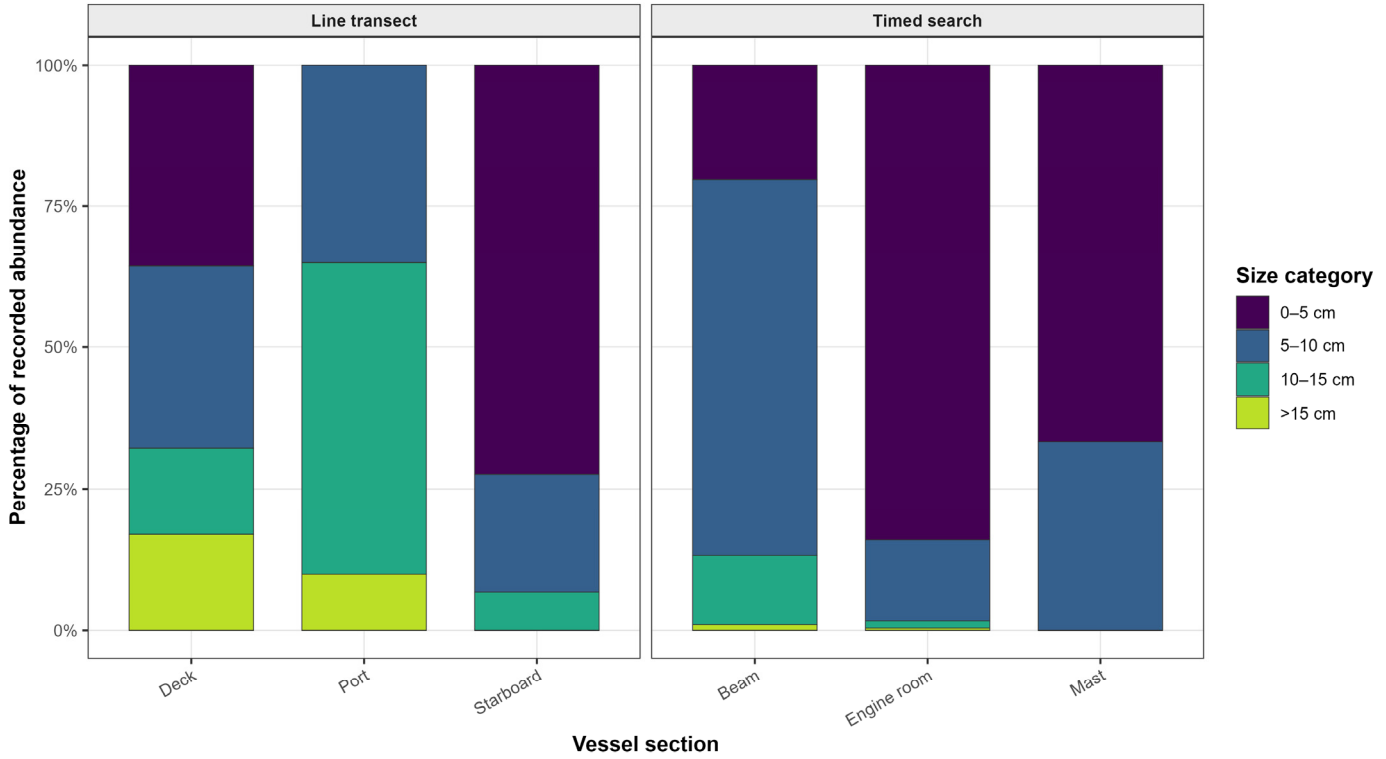

Figure 3. Percentage composition of fish total-length categories recorded within the surveyed sections of Lambousa II using timed search and line transects. Abundance was averaged between the two simultaneous observers before calculating the percentage contribution of each size category within each vessel section.

Size-category composition varied among vessel sections. The fish size range of 0–5 cm dominated the engine room, mast, and starboard, accounting for 84%, 66.7% and 72.4% of the recorded abundances, respectively. In contrast, fish measuring 5–10 cm were primarily characterised on the beam (66.3%) and port (55%) sections of the vessel. The deck displayed the most evenly distributed size composition and contained the greatest proportional contribution of fish larger than 15 cm (abundance = 16.9%).

3.3. Benthic Assemblages

A total of 11 biological taxa were identified across the 25 photoquadrats (Table 2). Turf algae was the most widespread biological cover category, occurring in 18 photoquadrats (72%) and contributing a mean cover of 32.2% across all quadrats. *Herdmania momus* occurred in 17 photoquadrats (68%) and had a mean cover of 13.0%.

Mean cover composition varied among vessel stations (Table 2). The engine room and cabin were characterised primarily by exposed metal structures (82% and 58% mean cover, respectively), with very limited biological growth. In contrast, the deck, starboard, and bridge were all dominated by turf algae, which accounted for 60.8%, 35.5%, and 70.5% of their respective compositions. Secondary categories in these areas included metal structure (20.3%) and *Herdmania momus* (13.7%) on the deck and *H. momus* (22.8%) and cyanobacteria (14.5%) on the starboard side. Meanwhile, the remaining stations showed more diverse or distinct communities: the port side displayed a highly distributed composition led by turf algae (23%), metal structure (19.8%), *H. momus* (17%), and branching tree-like hydrozoans (13.5%), while the beam was uniquely dominated by conglomerate algae–cyanobacteria (30%) and *S. cf. incrustans* (23%).

Biological cover also varied considerably across the photoquadrat sequence, ranging from 0% to 100%, with a mean of 64.6% (Figure 4). Biological richness ranged from zero to

six taxa per quadrat, with an overall mean of 2.52, and Shannon diversity ranged from 0 to 1.50, with a mean of 0.61. The greatest richness and Shannon diversity were recorded at starboard.

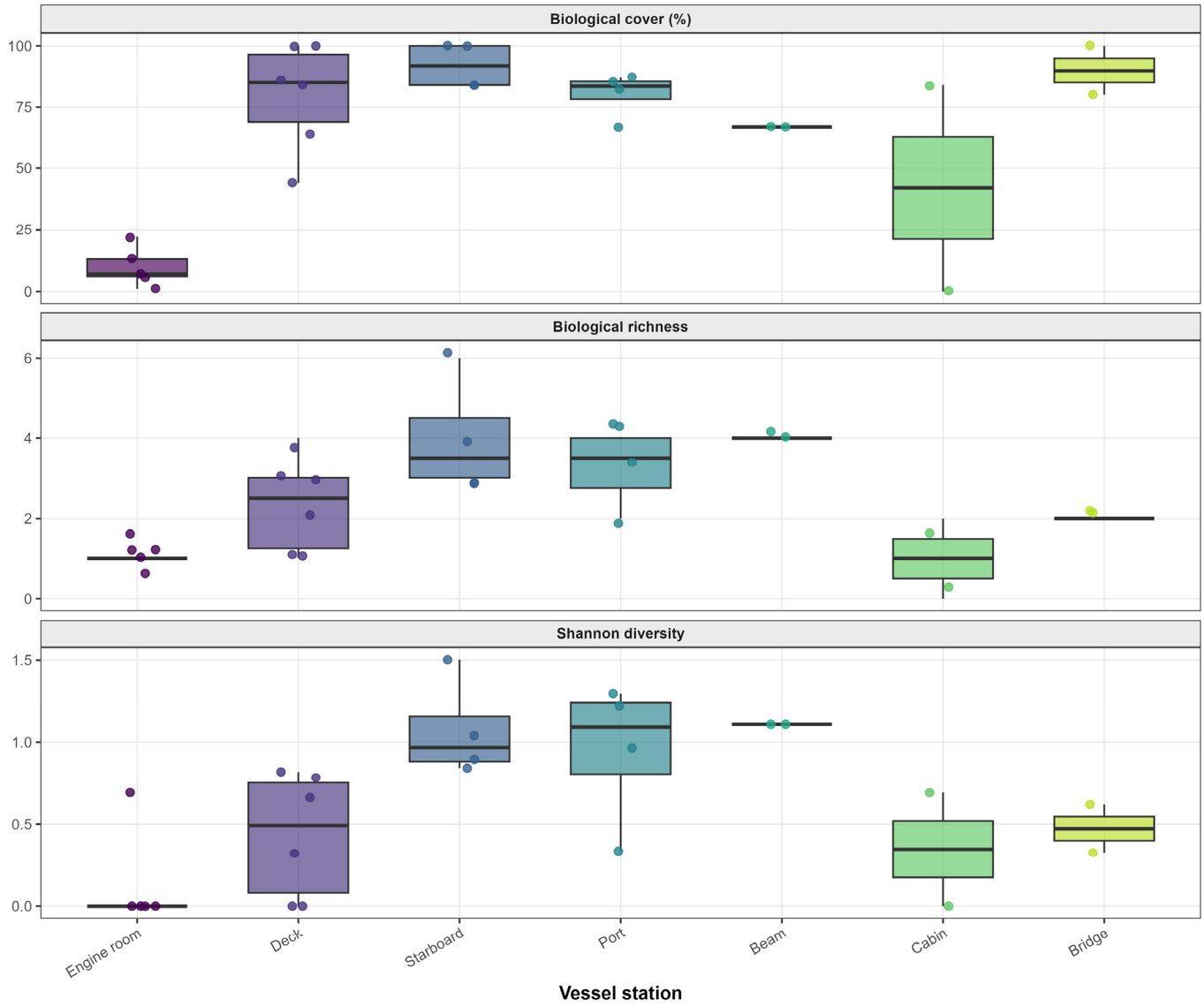

Figure 4. Biological cover, taxon richness, and Shannon diversity of photoquadrats collected from different stations on Lambousa II. Points represent individual photoquadrats. Boxes show the interquartile range, horizontal lines indicate the median, and whiskers extend to 1.5 times the interquartile range. Diversity calculations included biological cover categories only.

Table 2. Occurrence and percentage cover of the 11 biological taxa recorded across the 25 photoquadrats collected from Lambousa II. The asterix indicates that the species is classified as a non-indigenous species in the Mediterranean (NIS), and the number corresponds to the appropriate reference.

Taxon or Morphotype	Quadrats Occupied (n)	Frequency (%)	Mean Cover (%)	Maximum Cover (%)
Turf algae	18	72	32.16	93
Herdmania momus (Savigny, 1816) * [57]	17	68	13.00	54
Cyanobacteria	5	20	3.52	49
Conglomerate algae–cyanobacteria	3	12	3.36	30

Table 2. *Cont.*

Taxon or Morphotype	Quadrats Occupied (n)	Frequency (%)	Mean Cover (%)	Maximum Cover (%)
Salmacina cf. incrustans (Claparède, 1870)	4	16	3.00	23
Branching tree-like hydrozoan sp. 1	3	12	2.72	43
Long thin branching algae	3	12	2.24	36
Serpulidae	5	20	2.08	25
Short bushy white algae	2	8	1.72	34
Tethya aurantium (Pallas, 1766)	2	8	0.72	11
Short branching hydrozoan sp. 2	1	4	0.04	1

Station-level summaries revealed further spatial variation across the vessel. Mean biological cover was highest on the starboard side (92 ± 9.2%), closely followed by the bridge (90 ± 14.1%), while the engine room exhibited the lowest cover at 9.8 ± 8.0%. Mean taxonomic richness peaked at four taxa per quadrat on both the starboard side and beam, whereas the lowest richness was recorded in the cabin and engine room (1.2). Similarly, mean Shannon diversity index was highest on the beam (H′ = 1.11), followed by starboard (H′ = 1.07) and port (H′ = 0.95). Consistently, the lowest diversity occurred in the engine room (H′ = 0.14).

The two-dimensional NMDS (ordination stress = 0.0975; Figure 5) provided a good representation of biological community dissimilarity among photoquadrats. Considerable overlap occurred among photoquadrats from different vessel stations, indicating that the station groups did not form completely distinct assemblages. Nevertheless, variation in point positions and within-station dispersion demonstrated substantial small-scale heterogeneity in biological cover composition.

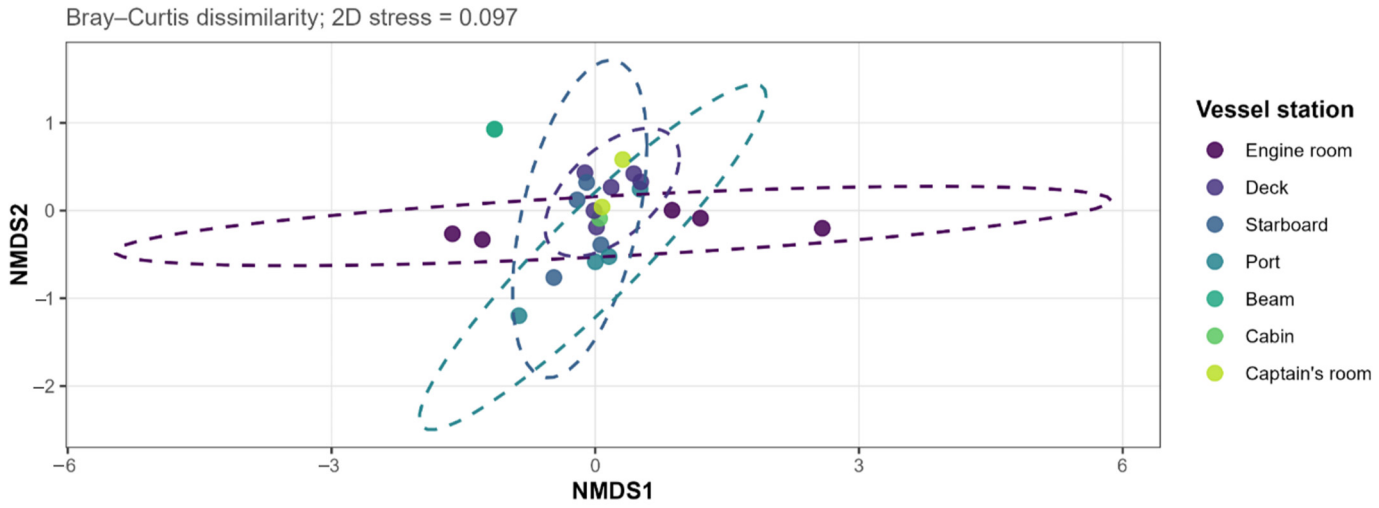

Figure 5. Two-dimensional non-metric multidimensional scaling (NMDS) ordination of biological photoquadrat composition based on Bray–Curtis dissimilarity calculated from square root-transformed percentage-cover data. Points represent individual photoquadrats and colours indicate vessel stations. Dashed lines show 95% confidence ellipses for stations represented by at least three non-empty photoquadrats. The photoquadrat without biological cover was excluded. The ordination stress was 0.0975.

Brush sampling yielded a total of 17 identified taxa. Spatial richness varied widely, ranging from a minimum of two taxa on both the port side and the corridor leading to the steering room to a maximum of 12 taxa collected outside the ship's bridge. Intermediary richness was observed in the mast and kitchen corridor samples, which contained seven

and five taxa, respectively. Among the recovered biological groups, amphipods were the most taxonomically diverse, with six identified taxa, followed by polychaetes with four. At the genus and species levels, the bryozoan *Amathia* sp. and the gastropod *Monophorus perversus* were the most ubiquitous, each occurring in six of the seven samples.

3.4. General Survey

The qualitative survey identified an additional two benthic species, the snakelocks anemone *Anemonia viridis* and the NIS brown alga *Padina boergesenii*, along with the egg sacs of the nudibranch *Felimare picta*.

3.5. Native vs. NIS Community Composition

NIS accounted for 86.5% of the summed mean fish abundance across the six surveyed sections, whereas native species accounted for 13.5% (Table 1; Figure 6). This pattern was strongly influenced by the high abundance of *Cheilodipterus novemstriatus* in the engine room and starboard. All six species recorded in the engine room and six in the steering room were NIS [50–56]. The starboard also contained NIS, with a total mean abundance of 72.5% individuals. On the deck, four NIS and two native species were recorded, with NIS representing 96.6% of the total abundance [50,53,55,56].

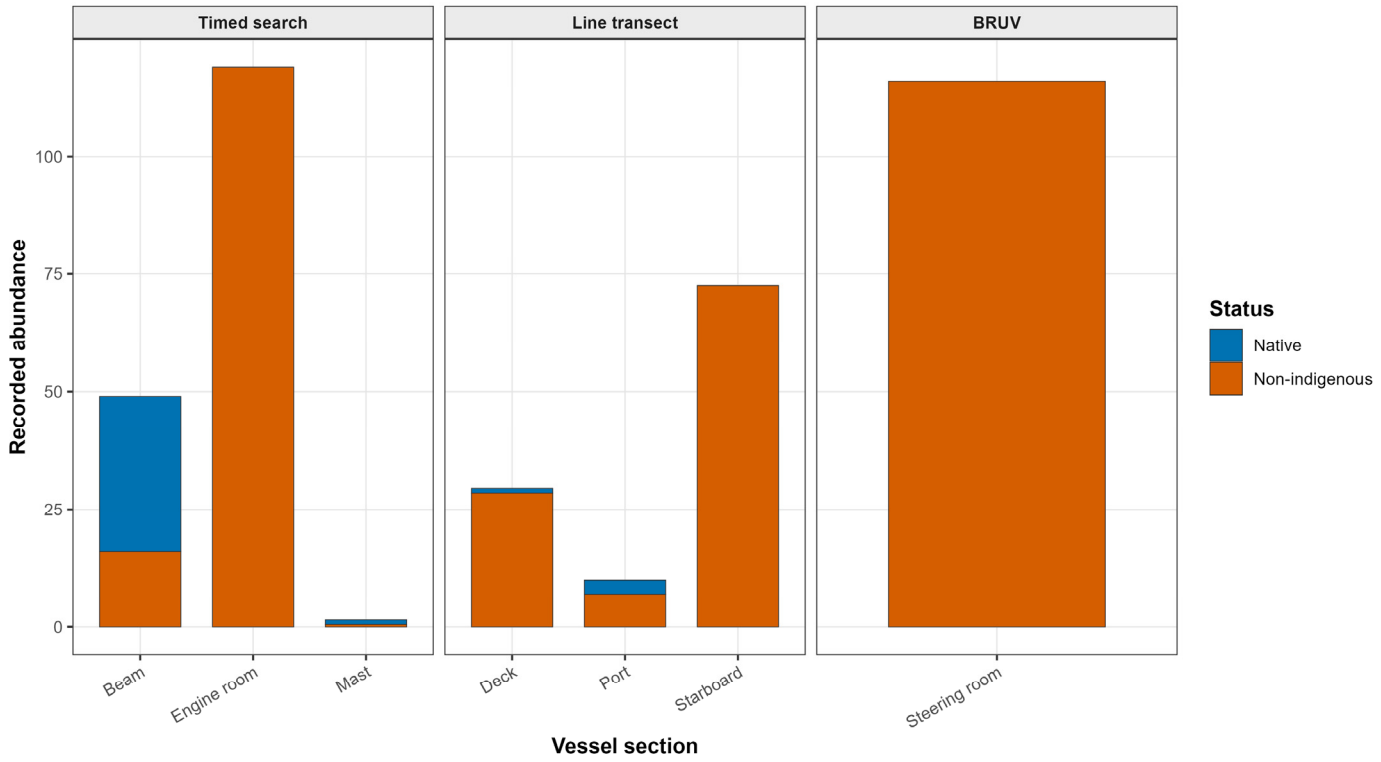

Figure 6. Mean abundance of native to non-indigenous fish species (NIS) across the surveyed sections of Lambousa II, presented separately for the time search, line transects and BRUV. UVC counts are observed means. BRUV is not included in the analysis.

In contrast, native fishes accounted for 67.3% of abundance at the beam, primarily because of the abundance of *Chromis chromis*. The mast contained one native species and one NIS, with native fishes representing 66.7% of abundance. At port, native and NIS richness were equal, with four species in each group, although NIS represented 70% abundance. All six species detected by BRUV were NIS.

Across the three surveyed benthic methodologies, four species, *Herdmania momus*, *Septifer cumingii*, *Diala semistriata*, and *Padina boergesenii*, were classified as NIS [57–59]. The

identification of *Diala semistriata* is specifically noteworthy as it is the first recording for Cyprus (Table 3; Figure 5).

Table 3. Classification of the specimens collected from the brush sampling at Lambousa II. The asterisk indicates that the species is classified as a non-indigenous species in the Mediterranean (NIS), and the number corresponds to the appropriate reference.

Group	Species	Semi-Dark				Light		
		Steering Room Corridor	**Engine Room**	**Kitchen Corridor**	**Deck**	**Port**	**Mast**	**Outside Bridge**
Amphi-pod	*Aora gracilis* (Spence Bate, 1857)					x		
	Dexamine spinosa (Montagu, 1813)							x
	Microdeutopus gryllotalpa (A. Costa, 1853)							x
	Stenothoe eduardi (Krapp-Schickel, 1976)			x				
Crustacea	*Chondrochelia dubia* (F) (Krøyer, 1842)						x	x
	Chondrochelia dubia (M) (Krøyer, 1842)							x
Bivalve	*Septifer cumingii* (Récluz, 1849) * [43]		x	x				x
Bryozoan	*Amathia* sp.		x	x	x	x	x	x
Copepods	*Copepods* sp.							x
Foraminifera	*Cyclocibicides vermiculatus* (d'Orbigny, 1826)						x	x
Gastropod	*Monophorus perversus* (Linnaeus, 1758)	x		x	x	x	x	x
	Diala semistriata (R. A. Philippi, 1849) * [58]							x
Polychaete	*Filograna implexa* (Berkeley, 1835)			x			x	x
	Hermodice carunculata (Pallas, 1766)						x	
	Opheliidae					x		
	Ophelina sp. 1							x
	Protula tubularian (Montagu, 1803)		x					
Porifera	*Sycon raphanus* (Schmidt, 1862)	x	x				x	

3.6. New Record

Family Dialidae (Kay, 1979).

Diala semistriata (R.A. Philippi, 1849; Figure 7).

Material examined: One empty shell, 20 m depth, outside the captain's bridge wall during the brush sampling in April 2026.

Description: Our shell is small (1 mm), thin, translucent, and elongated conical with 2 protoconch whorls and some five nearly flat teleoconch whorls. Its surface is rather smooth, with a well-marked suture. The body whorl is angled at its periphery, with more spiral grooves on its base. There is no axial sculpture. The aperture is entire, ovate to rhomboidal, with a thin outer lip and an oblique thin columella. Colour yellowish with light brown flames that convey a chequered outlook.

Distribution: The species originates from the Indo–Pacific and inhabits algae, seagrass and coral rubble in shallow subtidal areas [45]. Although an alien in the Mediterranean Sea, it is known in Egypt, Israel, Lebanon and Turkey [60–64].



Figure 7. Species *Diala semistriata,* the first recording of the NIS species in Cyprus, collected from the vessel Lambousa II. The total length of the specimen was 2 mm.

4. Discussion

The present study presents the first biological assessment associated with the recently deployed artificial reef vessel Lambousa II within the Boroklini–Larnaka MPA, approximately one year after its deployment. The findings provide evidence supporting all three initially stated hypotheses. The occurrence of turf algae, ascidians, hydrozoans, bryozoans, and other sessile and mobile taxa indicates that Lambousa II has developed into a benthic assemblage successional [65,66]. Moreover, the 16 recorded fish species, including commercially important species and juveniles, support the hypothesis that the structural complexity of the vessel provides habitat and shelter for a diverse fish assemblage, while lastly, the observed differences in biological cover, taxonomic richness, fish abundance, and the distribution of native and non-indigenous species among vessel sections support the hypothesis that benthic and fish communities vary spatially across the vessel [66–69]. Despite its relatively short deployment period, the new artificial structure has become integrated into the surrounding environment, supporting a diverse assemblage of invertebrate and ichthyofaunal taxa. However, it is important to recognise that the vessel-associated community, in terms of abundance, species richness, and species composition, is likely to vary with season and the progression of ecological succession on the artificial reef (AR). Consequently, the observed assemblage alone does not establish the effectiveness of either the MPA or the artificial structures in promoting long-term fish stock replenishment [70].

4.1. Early Ecological Development

The mean biological cover, together with the occurrence of turf algae, ascidians, hydrozoans, bryozoans and other sessile and mobile taxa, indicates that the vessel has already undergone substantial biological integration into the surrounding environment [66,67,71,72].

The pronounced spatial heterogeneity among vessel sections suggests that colonisation is strongly mediated by local structural characteristics. Moreover, several of the fish species identified on the wreck have been documented on several other wrecks in the Mediterranean as well [66–68]. Continued seasonal monitoring is therefore necessary to determine whether the communities observed during the current monitoring survey represent a transient early-successional assemblage or will develop into more stable communities over time [70].

4.2. Fish of Commercial Importance

The Boroklini–Larnaka MPA and associated deployed artificial reefs were established to conserve and enhance commercial fish stocks and marine ecosystem [23,25]. The current monitoring has demonstrated that Lambousa II is being used by at least 16 fish species and supports a developing benthic biological community. Of the 13 identified fish species, three—*Seriola dumerili* (Greater Amberjack), *Siganus rivulatus* (Marble Spinefoot) and *Parupeneus forsskali* (Red Sea Goatfish)—are of high commercial value for Cyprus, and three—*Obada melanura* (Saddle Seabream), *Pterois miles* (Lionfish), and *Sargocentron rubrum* (Red squirrelfish)—are of medium to low value [73,74]. These species are characterised by varying life histories; however, the deployed vessel communities seem to be able to supply prey suited to each of their different diets.

Although the diets and trophic pathways of these commercially important fish species were not investigated in the present study, they have been extensively examined in the peer-reviewed literature. For example, *Seriola dumerili* is an opportunistic predator that has previously been identified preying on Sparidae, Trachinidae, Mullidae, Synodontidae, and Labridae as well as on a range of molluscs, for which species of these families have been identified on the submerged vessel—i.e., *Oblada melanura, Trachinus radiatus, Parupeneus forsskali, Synodus saurus,* and *Thalassoma pavo* [75–77]. *Siganus rivulatus*, on the other hand, is known as an herbivorous grazer that consumes algae and turf algae, which have been documented to cover large areas of the vessel [78]. The third species of high commercial importance, *Parupeneus forsskali,* is known as a benthic opportunistic predator with a diverse diet [38]. Stomach content analysis of 249 specimens in Cyprus revealed that crustaceans—specifically from the orders Tanaidacea, Amphipoda, and Copepoda, along with gastropods and polychaetes, were the most important prey items for adults, whereas copepods represented the most vital prey for juveniles [79]. The brush sample analysis from the current investigation has identified the following species as possible prey items of *P. forsskali*: *Aora gracilis*, *Dexamine spinosa*, *Microdeutopus gryllotalpa*, and *Stenothoe eduardi* (Ampipoda); *Chondrochelia dubia* (Tanaidacea); *Diala semistriata* and *Monophorus perversus* (Gastropoda); and *Protula tubularian* and *Filograna implexa* (Polychaeta). Similarly, *Oblada melanura*, a generalist omnivore, has been documented feeding on Copepoda, Amphipoda, Polychaeta, Tunicata and Mollusca, as well as fish eggs (including the same species) and postlarvae and juvenile *Chromis chromis* [80]. The lionfish, *Pterois miles*, displays the life history of a very successful opportunistic, generalist carnivore, consuming most fish recorded on the vessel small enough to pass through its gape [81,82].

The occurrence of these commercially important fish species, alongside a diverse assemblage of potential prey and the presence of both native and non-indigenous species, suggests that Lambousa II may be facilitating the development of a complex trophic network involving multiple feeding pathways. However, as the present study did not investigate the feeding ecology of these fish species, further research is required to establish the extent of these trophic interactions. In particular, the coexistence of native and non-indigenous species may contribute to the emergence of food-web structures that differ from those historically characterised in Mediterranean coastal ecosystems. This can be supported

by Tsado et al., 2023, where it was shown that Lessepsian migrants altered their dietary preferences following their establishment in the Eastern Mediterranean, with *Sargocentron rubrum* showing a preference to native Mediterranean prey despite the availability of non-indigenous prey [83]. Such dietary shifts may have broader implications that need further investigating for trophic interactions, including potential predator–prey mismatches, shifts in prey selection, and changes in energy and nutrient pathway transfers within coastal food webs.

4.3. Juvenile Shelter

The presence of small-bodied fish on Lambousa II suggests that the vessel may provide suitable shelter for early development. More specifically, the vessel hosted early recruitments and juveniles of the species *Siganus rivulatus*, *Parupeneus forsskali*, *Oblada melanura*, *Pterois miles*, *Trachinus radiatus*, *Torquigener flavimaculosus* and *Chromis chromis*, which have varying ecological characteristics and life histories (Refs. [79,84–97]; Table S1). The structural complexity of the vessel, notably the diver-restricted section, may contribute to these observations by providing refuge from predation while also offering access to food resources [98]. Seasonal monitoring would be necessary to confirm repeated occupancy of the vessel by juvenile fish and identify periods of recruitment.

4.4. Native vs. Non-Indigenous Species

Native and NIS richness were relatively similar on Lambousa II, with a ratio of 6:7 species, respectively. This, however, was not directly reflected in the abundance, with NIS abundance being approximately six times greater than that of native species. The assemblages were compositionally distinct due to the presence of *Cheilodipterus novemstriatus*, which accounted for 310 out of the 487 NIS individuals. Yet, it is important to note that even without the presence of *C. novemstriatus*, the NIS-to-native abundance ratio was still disproportional, with the remaining non-indigenous assemblage overpowering the natives by 2:1. The spatial distribution further suggests that this pattern is not uniform across the vessel, with native species locally dominating areas such as the beam and mast (largely due to the abundance of *Chromis chromis*), whereas NIS dominated several other sections, particularly the engine room and deck. These findings align with the previous literature, which documents artificial structures harbouring a greater abundance of non-indigenous species without necessarily supporting a greater diversity relative to native communities [99,100].

In contrast, the benthic community (identified species) was heavily dominated by natives at a ratio of 16:4. The two most notable benthic Lessepsian species of the vessel were *Herdmania momus*, due to its dense widespread colonisation of the vessel, and *Diala semistriata*, as the first recording for Cyprus. Herdmania sp. colonising wrecks and AR in high abundances has previously been documented off the coast of Australia [66]. As an ascidian, *H. momus* serves as a distinct microhabitat that can essentially harbour an entire community of associates (endo, ecto and epi), and, as such, requires further investigation [101–103]. The gastropod *D. semistriata* is a long-known inhabitant of the Mediterranean Sea that has only just now been identified in Cyprus, a fact that in essence indicates that the Cypriot molluscan biodiversity is not yet explored adequately and that more species are waiting to be discovered [59–64,104,105].

These findings carry broader implications for regional conservation that have been under debate in recent years. Do MPAs act as safeguards, promoting and conserving local biodiversity, or do they act as refuge for non-indigenous species/biological invasions [15,65,105–108]. Widespread research across the Boroklini–Larnaka MPA and other

regional/mediterranean MPAs is required to provide substantial, long-term evidence for this trend.

5. Conclusions

The findings from the present study demonstrate that Lambousa II has rapidly become incorporated into the surrounding marine environment, supporting a developing benthic assemblage and a diverse fish community, including commercially important species and juveniles. Additionally, the pronounced spatial variation in community composition highlights the external influence on biological colonisation and fish distribution. Notably, the contrasting patterns observed between benthic and fish communities, with native taxa predominating among identified benthic species and non-indigenous species dominating fish abundance, underscore the complexity of artificial reef ecosystems and Marine Protected Areas. Although the vessel appears to provide habitat, shelter, and potential feeding resources for fish, the high abundance of non-indigenous fish species raises questions regarding the role of artificial structures in facilitating their establishment. These findings provide an important baseline for future assessments, while highlighting the need for long-term seasonal monitoring to evaluate the longitudinal ecological succession of the vessel, seasonal variation, and the implications of artificial reef deployment for native biodiversity and non-indigenous species establishment.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/hydrobiology5040047/s1, Table S1. Summary of data recorded during the UVC surveys, including method, location, species, size range, abundance, and size at first maturity. Superscript numbers next to species names indicate the references for the corresponding size-at-first-maturity data; Figure S1. Two-dimensional non-metric multidimensional scaling (NMDS) ordination of fish assemblage composition among vessel stations. The ordination stress was 0.045; Table S2: NMDS scores for the fish visual census; Table S3: NMDS scores table for the 25 photo quadrats; Supplementary methods information.

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Abbreviations

The following abbreviations are used in this manuscript:

MPA	Marine Protected Area
NTZs	No-Take Zones
AR	Artificial Reef
UVC	Underwater Visual Census
BRUV	Baited Remote Underwater Video
NIS	Non-Indigenous Species

NMDS Non-Metric Multidimensional Scaling

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