Jurnal Natur Indonesia
22(1), April 2024: 68-75

p-ISSN 1410-9379
e-ISSN 2503-0345

Hydro-Oceanographic Dynamics in the Rupat Utara Coastal Area

Dinamika Hidro-Oseanografi pada Kawasan Pesisir Rupat Utara

Ilham Ilahi[*1], Mubarak[1], Maellynia Mustofa[1], Novia M. Afianti[1]
[1]Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau, Pekanbaru 28293 Indonesia
*Correspondent Author: ilhamilahi@lecturer.unri.ac.id

ABSTRACT

Coastal areas are one of the areas that have very potential both functionally and economically as a source of life for the surrounding community. However, if the management of coastal resources does not have sustainability, various problems will arise. Rupat Island is one of the water areas that is a crossing path between countries. Sustainable management of coastal areas must follow planning, utilization, supervision, and control of the impact that will be caused both by humans in utilizing it and the effect of oceanographic phenomena on coastal areas, such as hydro-oceanographic factors. This research aims to analyze the characteristics and factors that cause coastal environmental degradation, as well as the ecological carrying capacity of coastal areas in terms of physical aspects of oceanography. The method used in this research is a survey method, which involves interviews and questionnaires analyzed qualitatively and quantitatively. Data collection was done using a purposive sampling method based on affordability. The resulting bathymetric contours indicate that the waters in the middle of the Malacca Strait have a high depth (40 m) with more inland areas (approaching Rupat Island), and the sea depth decreases. The tides shown are field and secondary tides obtained through the prediction of tidal data by NAOTide software. The results of the graph displayed are very appropriate, which shows that the tidal type of Rupat Utara is a mixed tide inclined to double daily (Mixed Tide Prevailling Semi-diurnal). Current patterns from low to high tide have the same direction, from the northeast towards the southeast, with the highest current velocity occurring in February and the current velocity value above 0.5 m/s. While at high tide towards low tide, the current pattern has the opposite direction, namely from the southeast to the northeast, with the highest current speed occurring in December and above 0.8 m/s. The IKP calculation of the entire research area of Tanjung Punak Village is the area with the highest vulnerability level value, with a GPA value of 1215, and the lowest vulnerability level value in Tanjung Medang Village, with a GPA value of 216. The phenomenon of coastal area damage in the Rupat Utara area is almost found in every observation location, which is caused by the impact of both hydro-oceanographic factors and anthropogenic factors.

Keywords: Hydro-Oceanographic Dynamics, Coastal Area, Coastal Damage Identification

ABSTRAK

Kawasan pesisir salah satu kawasan yang sangat potensial baik secara fungsi maupun secara ekonomis sebagai sumber kehidupan bagi masyarakat sekitar, namun apabila dalam pengelolaan sumberdaya pesisir tidak memiliki adanya keberlanjutan maka akan timbul berbagai permasalahan. Pulau Rupat merupakan salah satu kawasan perairan yang menjadi jalur perlintasan antar negara. Pengelolaan wilayah pesisir secara keberlanjutan harus sesuai dengan perencanaan, pemanfaatan, pengawasan serta pengendalian terhadap dampak yang akan ditimbulkan baik dari manusia dalam memanfaatkannya maupun dampak fenomena oseanografi terhadap kawasan pesisir seperti faktor hidro-oseanografi. Tujuan dari penelitian ini adalah menganalisis karakteristik dan faktor-faktor penyebab terjadinya degradasi lingkungan pesisir, serta daya dukung lingkungan kawasan pesisir ditinjau dari aspek fisik osenaografi. Metode yang digunakan dalam penelitian ini adalah metode survei dengan cara wawancara dan kuesioner dianalisis secara kualitatif dan kuantitatif. Pengumpulan data dilakukan dengan metode purposive sampling, yakni berdasarkan keterjangkauan. Kontur batimetri yang dihasilkan mengindikasikan bahwa perairan di tengah Selat Malaka memiliki kedalaman yang tinggi (40 m) dengan semakin ke daerah daratan (mendekati pulau Rupat) dan kedalaman lautnya semakin berkurang. Pasang surut yang ditampilkan adalah pasang surut lapangan dan pasang surut sekunder yang diperoleh melalui prediksi data pasang surut *Software NAOTide*. Hasil grafik yang ditampilan sangat sesuai yakni menunjukkan bahwa tipe pasang surut Rupat Utara adalah campuran condong ke harian ganda (*Mixed Tide Prevailling Semidiurnal*). pola arus saat surut menuju pasang memiliki arah yang sama yakni dari arah timur laut menuju kearah tenggara dengan kecepatan arus tertinggi terjadi pada bulan februari dengan nilai kecepatan arus berada di angka diatas 0,5 m/s. Sedangkan saat pasang menuju surut, pola arus memiliki arah sebaliknya yakni dari tenggara menuju timur laut dengan kecepatan arus tertinggi terjadi pada bulan desember dengan nilai kecepatan arus berada diatas 0,8 m/s. Perhitungan IKP dari keseluruhan wilayah penelitian Desa Tanjung Punak merupakan wilayah dengan nilai tingkat kerentanan tertinggi, dengan nilai IPK

Received: 20 March 2024
Accepted: 20 April 2024

1215 dan nilai tingkat nilai kerentanan terendah pada Desa Tanjung Medang dengan nilai IPK 216. Fenomena kerusakan wilayah pesisir pada wilayah Rupat Utara ini hampir ditemukan pada setiap lokasi pengamatan yang mana hal ini diakibatkan dampak baik secara faktor hidrooseanografi maupun oleh *anthropogenic*.
.

Kata Kunci: Dinamika Hidro-Oseanografi, Kawasan Pesisir, Identifikasi Kerusakan Pesisir

INTRODUCTION

Coastal areas are one of the most potential and strategic areas in the development and welfare of the community, and this is because coastal areas have rich natural resources, both biological and non-biological. However, using the coastal regions for development activities, both in business and other activities directly in contact, will impact the coastal environment. Along with the passage of time, impacts, and the emergence of new concepts in managing coastal areas, the utilization of coastal and marine resources must be conservative and environmentally sound (Mulyadi et al., 2017). Coastal regions have the most potential, both functionally and economically, as a source of life for the surrounding community. However, if the management of coastal resources does not have sustainability, various problems will arise. Rupat Island is one of the outermost islands in the administrative area of Bengkalis Regency, Riau Province, located in the northern part of the Malacca Strait and directly adjacent to Malaysia. Rupat Island is one of the water areas that is a crossing route between countries. Rupat Strait is part of the Malacca Strait and is known as semi-closed waters, with currents that fluctuate and are controlled by the rainy season (Mubarak et al., 2020).

The number of activities in direct contact with the coastal area of Rupat Island will impact both ecology and habitat, and it is very necessary to pay attention to the suitability between the needs and capabilities of the area in maintaining the stability of the coastal area. The management of the coastal regions in a sustainable manner must follow planning, utilization, supervision, and control of the impact that will be caused both by humans in utilizing it and the effect of oceanographic phenomena on coastal areas, such as hydro-oceanographic factors that affect it. Therefore, it is necessary to study oceanographic physics at the border as a mitigation effort in maintaining the land area of the border islands of the two countries. The purpose of this research is to analyze the physical oceanographic characteristics. Analyzing the physical oceanographic characteristics of the waters and coast of Rupat Island. Analyzing the driving factors that cause degradation of the coastal environment. Analyzing the carrying capacity of the coastal area environment in terms of physical oceanographic aspects.

MATERIALS AND METHOD

This research was conducted from June to December 2023, located in the northern part of Rupat Island, Bengkalis Regency, Riau Province, focusing on coastal areas and waters of the Malacca Strait and Rupat Strait (Figure 1).

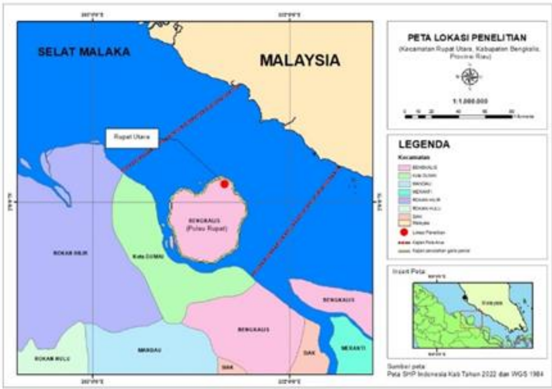

Figure 1. Research location

The tools and materials used in this research are a PC or laptop with 4 GB RAM, 64 bit, Google Earth, global mapper, QGis, Notepad, MIKE 21, mobile phone camera, stationery, simple tidal bar, current drogue, GPS (Global Positioning System) Map camera, Arcgis, thermometer, secchi disk, hand refractometer, Microsoft word 2010 and Microsoft Excel 2010, Landsat 8 OLI/TIRS image coastline data (https://earthexplorer.usgs.gov) NAOTide tide prediction data, BMKG wind data (www.bmkg.go.id), DEMNAS bathymetry data (https:

Tanahair.indonesia.go.id). The method used in this research is a survey method, which involves interviews and questionnaires analyzed qualitatively and quantitatively. Primary data used direct observation methods in the field to determine the condition and potential of coastal areas and policies in management in the research area to achieve research objectives. Secondary data was obtained from information from various parties related to the research, such as government and private agencies. Data collection was carried out using the purposive sampling method based on affordability.

RESULT AND DISCUSSION

Bathymetry

The depth of the eastern Rupat Strait ranges from 0.4 - 24.8 m (Rifardi, 2021). based on data processing, the water depth ranges from 5-40 m with an interval of 5 m (Figure 2).

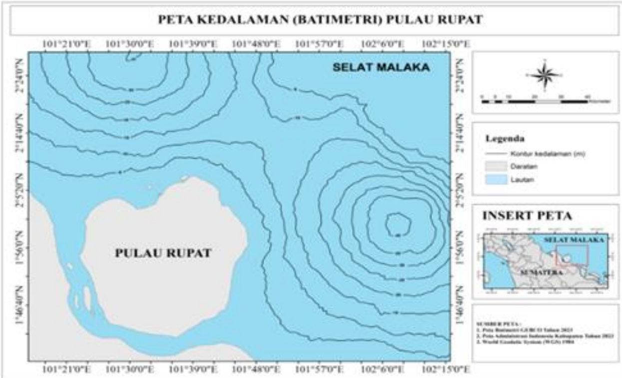

Figure 2. Depth map (bathymetry) of Rupat Island

The resulting bathymetric contours indicate that the waters in the center of the Malacca Strait have a high depth (40 m), with the sea depth decreasing further inland (closer to Rupat Island). Based on the topographic shape, several ridges are formed in the Rupat Strait, and the deepest depths are generally observed in the strait's center (Mubarak et al., 2020). The increase in depth occurred over the years despite the strait receiving large amounts of rainfall and fine-grained sediment discharged by rivers and channels from the hinterland of Dumai City and Rupat Island (Rifardi, 2021).

Tides

Based on the value of the tidal component, the Formzahl value of 0.13748 is obtained; this indicates that the waters of Rupat Utara Island have a mixed tide type tending to double daily (Mixed tide prevailing semi-diurnal). More details can be seen through Figure 3.

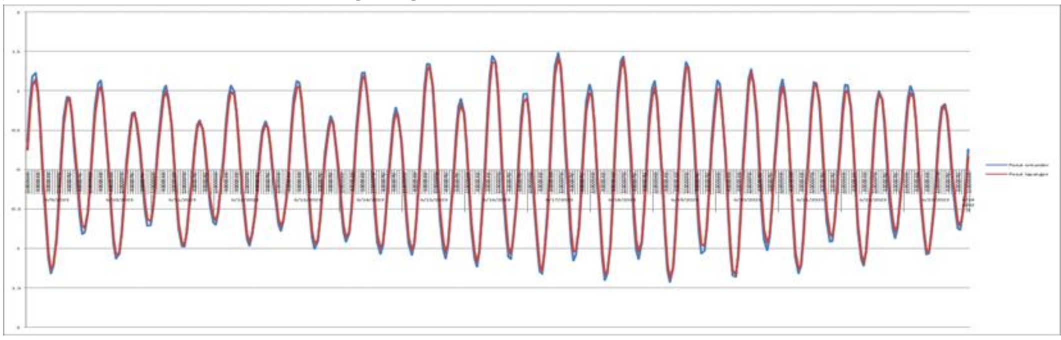

Figure 3. Tidal validation

Based on Figure 3, it is known that the shape of the tidal graph displayed is the field tides and secondary tides obtained through the prediction of NAOTide Software tidal data. The results of the graph displayed are very suitable, which shows that the tidal type of Rupat Utara is mixed tide, leaning to double daily (mixed tide prevailing semi-diurnal). In addition, the graph will prove that the secondary data used as processed data is correct following field data. Tides in Rupat Strait occur twice a day or semi-diurnally, where the highest tide reaches 1.26 m, while the lowest is -1.37 m. Based on the calculation, the tidal type in the waters of Rupat Strait obtained a Formzhal

Number value of 0.21, indicating that it is a mixed tidal type that tends to be twice daily (Mubarak et al., 2022)

Wind

Analysis of wind data blowing at sea level processed in the West and East seasons in 2022 for 24 hours for the Rupat Island area. In the west season, the highest according to the average wind speed is in the western part, with the dominant speed ranging from 2.08 - 3.80 m/s. According to the average wind speed, the highest east wind season is in the eastern part, with dominant speeds ranging from 0.70-2.30 m/s. Winds with a calm category can be influenced by the geographical conditions of the wind observation location and wind flow obstacles in the form of land or islands around it (Mubarak et al., 2020).

Current

Processing of the current model is carried out using a two-dimensional numerical model, where the visualization of the model is taken during the two west and east seasons, and data is taken from high tide to low tide and low tide to high tide each season. Mesh boundaries were created based on the study area using shoreline data and bathymetry data as input (Figure 4).

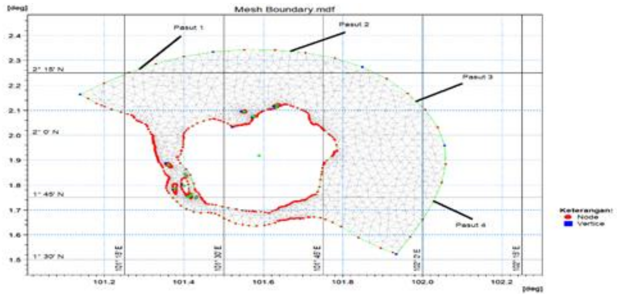

Figure 4. Boundaries of the research location model

The current model obtained has varying current velocity results. The movement of the current direction has a direction that tends to be the same every season when the tide conditions recede and vice versa.

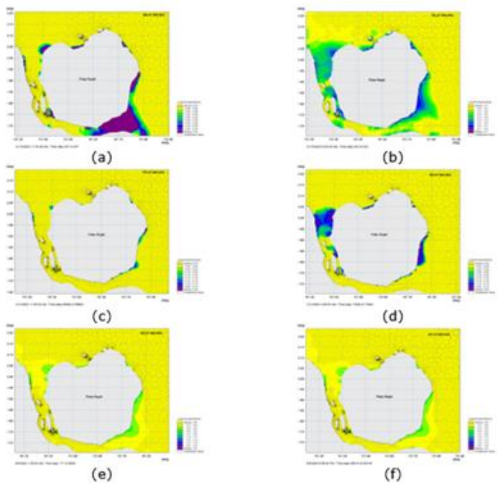

Figure 5. December-February ebb-to-tide current model ((a), (c) and (e)) and December-February ebb-to-tide current model ((b), (d) and (f))

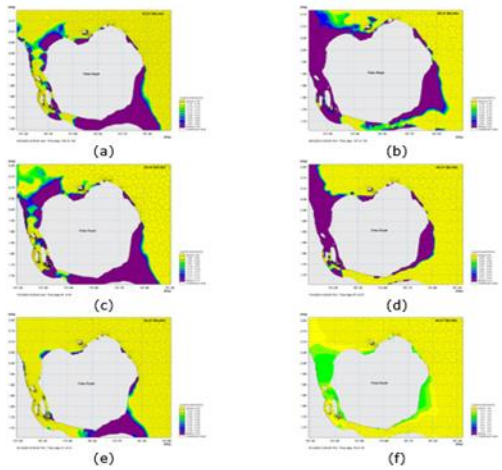

Figure 6. June-August ebb-to-tide current model ((a), (c) and (e)) and June-August ebb-to-tide current model ((b), (d) and (f)).

In the west season, the current pattern at low tide towards the tide has the same direction, namely from the northeast towards the southeast, with the highest current speed occurring in February with a current speed value above 0.5 m/s while at high tide towards low tide, the current pattern has the opposite direction, namely from the southeast towards the northeast with the highest current speed occurring in December with a current speed value above 0.8 m/s (Figure 5). In the east season, the current pattern at low tide to high tide has the same direction, namely from the northeast towards the southeast, with the highest current speed occurring in July with a current speed value above 0.89 m/s while at high tide to low tide, the current pattern has the opposite direction, namely from the southeast towards the northeast with the highest current speed occurring in June with a current speed value above 0.79 m/s (Figure 6). Changing seasons that are happening also influence the movement of the current. In the west season, the movement of the current is generally towards the east or east current, and vice versa. In the west season, the direction of the current is towards the east (Putri et al.,2014). Significant wave height produces currents along the coast at high speed, so that more and more beach material is eroded or lost to deeper beaches carried by coastal currents in the waters (Reza et al., 2020)

Mangrove vegetation types

Eleven mangrove species were identified at four research stations in the coastal area of Rupat Utara Island, and 11 mangrove species were found (Table 1).

Table 1. Mangrove species found in the Rupat Utara coastal area

No.	Family	Code	Scientific Name	Local Name
1	*Rhizophoraceae*	Exit	*Rhizophora apiculata*	Mangrove Oil
2	*Lythraceae*	Sa	*Sonneratia alba*	Pedada
3	*Rhizophoraceae*	Bg	*Gimnorriza Bruguiera*	Tanjang
4	*Meliaceae*	Xg	*Xylocarpus granatum*	Nyireh, Nyirih
5	*Rhizophoraceae*	Rm	*Rhizophora mucronata*	Black Mangrove
6	*Avicenniaceae*	Am	*Avicennia Marina*	White Fire
7	*Lythraceae*	So	*Sonneratia reed*	Gray
8	*Combretaceae*	Lr	*Lumnitzera racemosa*	Teruntum Puih
9	*Avicenniaceae*	Aa	*Avicennia alba*	Fire-fire
10	*Rhizophoraceae*	Rs	*Rhizophora stylosa*	Small mangrove forest
11	*Arecaceae*	Nf	*Nypa Frutican*	Nipah

The Rhizophoraceae family dominates mangrove species in the study area, and it is thought that the mangrove species of the family dominate living in estuarine waters with mud and sandy mud substrate types. Besides that, rooting species from the Rhizophoraceae family have a texture as a binder of mud particles and organic matter for the growth of these types of mangroves. The global status of the five members of the Rhizophoraceae family in the Rupat Utara MPA is classified as least concern, namely species with a very low risk of extinction (Syahrial et al., 2020). Mangroves in the Rupat Utara District consist of 12 species with members of the Rhizophoraceae family (*R. apiculata, R. mucronata, Bruguiera gymnorrhiza, B. sexangula, Ceriops tagal*) dominating (Syahrial et al., 2023).

Mangrove vegetation composition

The analysis of mangrove species composition found in the field shows that the composition of mangrove species that are more dominant in inhabiting a location is known. The composition of mangrove species can be presented in Table 2.

Table 2. Mangrove vegetation composition

Station	Ra	Sa	Bg	Xg	Rm	Am	So	Lr	Aa	Rs	Nf
I	+	+	+	+	+	+	-	-	-	-	-
II	+	+	+	+	+	-	+	+	-	-	-
III	+	+	+	-	+	+	+	+	+	+	-
IV	+	+	+	+	+	+	-	+	-	-	+

Description: (+) = Found; (-) = Not found; *Ra* : *Rhizophora apiculata*; *Rm*: *R.mucronata; Sa*: *Sonneratia alba; Am*: *Avicennia marina;Bg*: *B. Gimnorriza; So*: *S.ovata; Xg*: *Xylocarpus granatum; Lr*: *Lumnitzera racemosa; Aa*: *A. Alba; Rs*: *R.stylosa; Nf*: *Nypa frutican*

The diversity of mangrove species in the Rupat Utara area is quite diverse. This is thought to be because the level of adaptation of a mangrove species to keep growing in this area is different; this is what causes differences in the composition and structure of mangrove vegetation communities in the Rupat Utara area. Major mangroves are plants that live entirely in tidal mangrove ecosystems, do not grow in other ecosystems, and adapt morphologically and physiologically to live in a mangrove environment (Ghufrona et al., 2015).

Mangrove community structure analysis

Species diversity in the study area looks diverse; 11 types of true mangroves in the tree category were found. Overall, it can be seen that the diversity of mangroves in each area of Rupat Utara varies between 6 - 9 species. The analysis results obtained at each station of this study are presented in Table 3.

Table 3. Mangrove community structure

Station	Type	Total	K (ind/ha)	KR	F	FR	BA	D	DR	NP (%)
ST.I	*Ra*	82	911,11	44,09	1,00	34,62	2798,62	3,11	45,53	124,24
	Sa	14	155,56	7,53	0,56	19,23	401,49	0,45	6,53	33,29
	Bg	30	333,33	16,13	0,56	19,23	1322,55	1,47	21,52	56,88
	Xg	31	344,44	16,67	0,44	15,38	1054,24	1,17	17,15	49,20
	Rm	23	255,56	12,37	0,22	7,69	469,61	0,52	7,64	27,70
	Am	6	66,67	3,23	0,11	3,85	99,73	0,11	1,62	8,69
Total		186	2066,67	100,00	2,89	100,00	6146,231	6,83	100,00	300,00
ST.II	*Ra*	66	733,33	45,21	1,00	37,50	1556,91	1,73	42,96	125,66
	Rm	28	311,11	19,18	0,44	16,67	1035,04	1,15	28,56	64,40
	Sa	17	188,89	11,64	0,33	12,50	478,53	0,53	13,20	37,35
	Lr	15	166,67	10,27	0,33	12,50	113,06	0,13	3,12	25,89
	So	1	11,11	0,68	0,11	4,17	12,43	0,01	0,34	5,19
	Xg	9	100,00	6,16	0,22	8,33	204,99	0,23	5,66	20,15
	Bg	10	111,11	6,85	0,22	8,33	223,45	0,25	6,17	21,35
Total		146	1622,22	100,00	2,67	100,00	3624,415	4,03	100,00	300,00
ST. III	So	10	111,11	4,10	0,22	6,90	228,2201	0,25	4,14	15,13
	Am	37	411,11	15,16	0,56	17,24	805,3527	0,89	14,59	47,00
	Aa	36	400,00	14,75	0,44	13,79	1009,351	1,12	18,29	46,84
	Sa	37	411,11	15,16	0,67	20,69	1041,746	1,16	18,88	54,73
	Rs	16	177,78	6,56	0,11	3,45	365,8362	0,41	6,63	16,63
	Ra	68	755,56	27,87	0,67	20,69	1567,352	1,74	28,40	76,96
	Bg	22	244,44	9,02	0,33	10,34	449,6985	0,50	8,15	27,51
	Lr	9	100,00	3,69	0,11	3,45	51,44696	0,06	0,93	8,07
	Rm	9	100,00	3,69	0,11	3,45	187,49	0,21	3,40	10,53
Total		244	2711,11	100,00	3,22	100,00	5706,496	6,13	103,40	303,4
ST. IV	Ra	59	655,56	23,98	0,89	25,81	1528,931	1,70	16,87	66,66
	Rm	56	622,22	22,76	0,78	22,58	1255,21	1,39	13,85	59,19
	Bg	39	433,33	15,85	0,56	16,13	816,2705	0,91	9,01	40,99
	Sa	32	355,56	13,01	0,56	16,13	830,3106	0,92	9,16	38,30
	Xg	29	322,22	11,79	0,33	9,68	4219,327	4,69	46,56	68,02
	Am	12	133,33	4,88	0,11	3,23	304,784	0,34	3,36	11,47
	Lr	19	211,11	7,72	0,22	6,45	108,1639	0,12	1,19	15,37
Total		246	2733,33	100,00	3,44	100,00	9062,997	10,07	100,00	300,0

The station I Kadur obtained six mangrove species, namely *R.apiculata, S.alba, B.gymnorrhiza, X. granatum, R.mucronata,* and *A.marina*. *R.apiculata* has a high-density value compared to the five species found, which is 911.11 Ind / Ha with a percentage of the important value of 124.24%, the lowest density value of Avicennia marina type of 66.67 Ind / Ha with an important value of 8.69. Station II has the lowest total mangrove density compared to the four observation stations, with a total density of 1622.22 Ind / Ha. Furthermore, station III Teluk Rhu obtained the most mangrove species found are *S. ovata, A. marina, A.alba, S. alba, R.stylosa, R. apiculata, B.gymnorrhiza, L.racemosa,* and *R.mucronata*. *Rhizophora apiculata* has a high-density value of 755.56 Ind / Ha with a percentage of the important value of 57.73%, and station IV Tanjung Medang area has the highest mangrove density in Rupat Utara of 2733.33 Ind / Ha. Tanjung Medang area has a river estuary that divides the island of Rupat, thus supporting the growth of mangroves.

Identification of coastal area damage

Calculation of the Coastal Vulnerability Index (IKP) shows that the condition of the coastal area of Rupat Utara has been degraded. The IKP calculation of the entire research area of Tanjung Punak Village is the area with the highest vulnerability level value, with a GPA value of 1215, and the lowest vulnerability level value in Tanjung Medang Village, with a GPA value of 216 (Table 4). The phenomenon of coastal area damage in the Rupat Utara area is almost found in every observation location, and this is due to the impact of hydro-oceanographic factors and anthropogenic factors. Development activities carried out in land, and coastal areas have a lot of negative effects on the environment, resulting in a decrease in the quality of the coastal and marine environment and natural resources, namely in the form of pollution, environmental damage, and excessive utilization of coastal and marine resources. The damage to coastal areas in this study occurs due to two causal factors, namely nature and human endorsement. Several conditions, especially hydro-oceanographic factors, cause natural factors. Anthropogenic factors are local community activities that do not heed the rules of nature and applicable policies. Especially land use change and mangrove forest logging (Fadilah, 2021)

Table 4. Identification of damage to Rupat Utara Coastal area based on IKP value

Station	Location	Cause of Damage	Impact	IKP	Alternative Countermeasures
1	Kadur	Mangrove Forest Damage, Patai accretion, land conversion to ponds	Mangrove Forest Degradation, siltation, land area expansion, seawater intrusion inland	486	Mangrove Forest Rehabilitation, creation of Green Belt, creation of local regulations and Perdes on land conversion
2	Tanjung Punak	Abrasion, land conversion to ponds, Mangrove Forest Damage	Seawater intrusion, mangrove forest degradation, damage to biota and fish habitat,	1215	Planting coastal forests, making local regulations and Perdes on land conversion.
3	Rhu Bay	Abrasion, land conversion, mangrove forest destruction,	Changes in coastal morphology, reduced beach width, loss of mangroves zonation, seawater intrusion inland	324	Counseling and providing knowledge to the community about mangrove and marine debt, making local regulations and perdes on land conversion
4	Tanjung Medang	Land conversion, mangrove forest destruction, abrasion	Beach degradation, seawater intrusion, partial loss of mangrove zoning, and fish depletion	216	making rules about cutting down mangrove forests and opening land conversion, making green belts

CONCLUSION

The resulting bathymetry contours indicate that the waters in the middle of the Malacca Straits have a high depth (40 m), with the more inland areas (Approaching Rupat island), the depth of the sea decreases. Tides displayed are field tides and secondary tides obtained through the prediction of tidal data NAOTide software. The results of the graph displayed are very appropriate, which shows that the tidal type of Rupat Utara is a mixed tide inclined to double daily (mixed tide prevailing semi-diurnal). The current pattern at low tide towards the tide has the same direction, namely from the northeast towards the southeast, with the highest current speed occurring in February with a current speed value above 0.5 m/s, while at high tide towards low tide, the current pattern has the opposite direction, namely from the southeast towards the northeast with the highest current speed occurring in December with a current speed value above 0.8 m/s. Calculate IKP from the entire study area of the village of Rupat Village. The IKP calculation of research as the whole area of Tanjung Punak Village has the highest vulnerability level value, with a GPA value of 1215, and the lowest vulnerability level value in Tanjung Medang Village, with a GPA value of 216. The phenomenon of coastal area damage in the Rupat Utara area is almost found in every observation location, which is caused by the impact of both hydro-oceanographic and anthropogenic factors.

REFERENCES

Fadilah, F., 2021 *Analisis faktor hidro-oseanografi terhadap kerusakan pantai Kecamatan Pondok Kelapa Kabupaten Bengkulu Tengah dan penentuan konsep penanganannya*. CV. Jakad Media Publishing. Surabaya

Ghufrona, R., Kusmana, C., Rusdiana, O., 2015. Species composition and mangrove forest structure in Pulau Sebuku, South Kalimantan. *J. Silvikultur Trop.*, 6(1): 15–26

Mubarak, M., Rifardi, R., Nurhuda, A., Sulaiman, A., 2020. The properties of sediment transport mechanism in river mouth of Rupat Strait. *Preprint:* 6–12

Mubarak, M., Rifardi, R., Riyadi, A., Sulaiman, A., Yoswati, D., Wibowo, M.A., 2022. On the salinity distribution induced mixing at the mouth of the estuary, *IOP Conf. Ser. Earth Environ. Sci.*, 1118(1): 1–7

Mulyadi, A., Yoswaty, D., Ilahi, I., 2017. Dampak lingkungan dari pengembangan ekowisata bahari di kawasan konservasi lamun Trikora, Bintan, Kepulauan Riau. *Berkala Perikanan Terubuk*, 45(1): 95–111.

Putri, M.P., Supriharyono, S., Muskananfola, M., 2014. Karakteristik hidro-oseanografi dan tingkat partisipasi masyarakat dalam menanggulangi kerusakan pantai di Desa Bedono, Kecamatan Sayung, Kabupaten Demak. *Journal of Maquares*, 3(4): 225–234.

Reza, A.W., Rifardi, R., Mubarak, M., 2020. Waves and tidal current on high tide (spring tide condition) in Rupat Strait Riau Province, *Jurnal Perikanan dan Kelautan*, 25(1): 1–5.

Rifardi, R., 2021. The bottom surface sediment transport changes in bathymetry in the Rupat Strait, Riau Province, Indonesia. *IOP Conference Series: Earth and Environmental Science*,

Syahrial, S., Erlangga, E., Sembiring, R.T.L., Syahrin, A., 2020. Famili Rhizophoraceae di hutan mangrove KKPD Rupat Utara Provinsi Riau Bagian I, Deskripsi Anggota. *Jurnal Sumberdaya Akuatik Indopasifik*, 4(2).

Syahrial, S., Hatta, M., Larasati, C.E., Ruzanna, A., Muzafri, A., Hasiud, L.O.A.F., Syahrian , W., Zibar, Z., 2023. Analisis multivariat pada struktur komunitas mangrove di Kecamatan Rupat Utara Kabupaten Bengkalis Provinsi Riau. *Jurnal Kelautan Tropis* 26(2):223–237