LAPORAN PENELITIAN
PENELITIAN DASAR UNGGULAN PERGURUAN TINGGI (PDUPT) TAHUN 1

Eksplorasi Ekosistem Bentik sebagai Bioindikator Kualitas Perairan dibidang Marine Bioprospecting Sumber Pangan Alternatif pada Kawasan Strategis Pesisir Sumatera Selatan (Musi Ecosystem Project / Musi Eco Pro) (Tahun 1)

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HALAMAN PENGESAHAN LAPORAN AKHIR
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C. **HASIL PELAKSANAAN PENELITIAN:** Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian meliputi data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

A. Status Keanekaragaman Komunitas Bentik di Pesisir Sumatera Selatan

Krustasea

Keanekaragaman spesies kepiting yang ditemukan di pesisir Sumatera Selatan (Gambar 1), yaitu *Uca dussumieri* (Edwards, 1852), *Metaplax longipes* (Stimpson, 1858), *Metaplax distinct* (Edwards, 1852). Selama pengambilan sampel, kualitas pengukuran perairan diambil secara in situ. Pada substrat ditemukan lumpur hitam halus dengan kedalaman 60 sampai 100 cm. Hasil parameter lingkungan yang diukur salinitas 27-29 psu, suhu 29-30°C, pH 6,08-6,2, nitrat 6,69 mg/L, dan fosfat 0,197 mg/L.

Gambar 1. Keanekaragaman spesies kepiting di pesisir Sumatera Selatan, A) *Uca dussumieri* (Edwards, 1852); B) *Metaplax longipes* (Stimpson, 1858); C) *Metaplax distinct* (Edwards, 1852)

Kepiting *Uca dussumieri* (Edwards, 1852) memiliki keunikan pada capitnya. Ketika capit besar rusak atau patah, ia akan tumbuh kembali atau capit lainnya akan membesar. Berwarna cerah kekuningan, dan ruam atau bergerigi pada permukaan dactylus, propodus dan carpus. Karapas menyerupai trapesium dengan sisi anterior yang lebih lebar dan ujung yang runcing, hal itu disebut karapas trapesium. Berwarna hitam kecoklatan, coklat tua dan jingga kehitaman (1). Bola mata berwarna hitam dan bulat dengan batang mata panjang mendekati ujung anterior karapas. Kepiting ini memiliki lima pasang kaki, terdiri dari satu pasang di bagian depan capit, dan empat pasang kaki berjalan. Perutnya berwarna kebiruan berbentuk segitiga memanjang. Berdasarkan ciri morfologinya, spesies ini tergolong *fiddler crab*, memiliki kemiripan dengan beberapa spesies lain seperti *Uca demani* dan *Uca urvillei* (2,3). Hal ini dapat ditemukan di daerah berlumpur daerah mangrove (4,5).

Kepiting *Metaplax longipes* (Stimpson, 1858) memiliki karapas coklat tua (Gambar 1.B). Karapas berbentuk bujur sangkar dengan bagian bawah yang lebih pendek atau disebut karapas persegi atau subkuadrat. Spesies ini memiliki sepasang capit yang berukuran sama dan lebih panjang dari empat pasang kaki berjalan. Capitnya berwarna oranye-coklat, sedangkan ciri lainnya adalah bagian propodus yang sangat panjang, daktil yang pendek, dan permukaan cheliped yang cukup halus (2). Bola matanya berwarna hitam dengan panjang batang mata memanjang ke ujung anterior karapas. Kepiting ini memiliki lima pasang kaki yang terdiri dari satu pasang capit dan empat kaki berjalan. Kaki kedua dan ketiga berjalan lebih panjang dari kaki pertama dan keempat. Perut berwarna coklat muda, dan memiliki bentuk segitiga memanjang. Genus spesies ini adalah *Metaplax* spp. dari famili Varunidae. Berdasarkan morfologi dan pohon filogenetik, spesies ini memiliki kemiripan dengan *Metaplax takahashii*, *Cyclograpsus granulosus*, *Helice wuana*, dan *Eriocheir japonica* (2,6). Hampir semua spesies dari genus ini ditemukan di habitat berlumpur di dekat ekosistem mangrove, juga ditemukan di substrat berpasir yang didominasi oleh air laut (6–8).

Kepiting *Metaplax distinct* (Edwards, 1852) memiliki karapas berbentuk persegi panjang dengan sisi agak membulat dan sisi bawah yang lebih pendek dari bagian atas yang disebut subkuadrat atau bujur sangkar. Karapas didominasi warna coklat tua, dengan kedua sisi anterior meruncing. Capit dari spesies ini pendek dan kecil dibandingkan dengan kaki berjalan, hal ini menunjukkan jenis kelamin betina, karena spesies betina ini memiliki sepasang capit yang lebih pendek dan lebih kecil dari pada spesies jantan (9,10). Capitnya didominasi merah kehitaman dengan dactyl oranye. Kedua bola mata berbentuk bulat hitam dengan batang yang memanjang hampir ke sisi luar anterior. Ada lima pasang kaki, satu pasang capit dan empat pasang kaki berjalan. Ukuran kaki jalan kedua dan ketiga lebih panjang dari kaki jalan pertama dan keempat. Spesies ini betina, dengan perut segitiga yang lebar dan bulat (11). Spesies ini memiliki kemiripan dengan *Metaplax gocongensis* dan *Metaplax indica* (12). Diklasifikasikan dalam famili Varunidae, disebut juga kepiting dengan habitat muara berlumpur, banyak ditemukan di kawasan mangrove dan pantai berpasir (8,13).

Spesies C1 merupakan spesies kepiting yang unik. Keunikannya ada pada bagian capit jantannya, sepasang capitnya memiliki ukuran berbeda. Di beberapa kondisi, capit terbesar spesies ini terdapat di sebelah kanan dan di beberapa individu ditemukan di sebelah kiri. Terkait hal ini, bentuk dan corak capit kedua spesies sama namun yang membedakannya hanya pada posisi capit terbesar dan terkecilnya saja. Beberapa penelitian terdahulu telah melaporkan keunikan spesies kepiting *Uca dussumieri*. Spesies *Uca dussumieri* ini memiliki keunikan pada capitnya, jika capit besarnya patah atau hilang maka capit besar itu akan tumbuh kembali pada keadaan semula. Namun proses capit besarnya tumbuh ada dua kemungkingan yang terjadi, kemungkinan pertama bisa tumbuh di capit terbesar yang mengalami kepatahan atau di tempat awalnya dan kemungkinan kedua bisa tumbuh dari posisi capit terkecilnya lalu capit kecil akan tumbuh lagi di tempat capit yang hilang (14–18). Keunikan spesies *Uca dussumieri* telah menjadi ciri khas sendiri untuk spesies fiddler crab ini yang berasal dari family Ocypodidae (3,19–21).

Spesies C1 ini sangat diduga sebagai spesies *Uca dussumieri*. Bentuk karapasnya yaitu trapezoidal dengan ujung anterior karapas yang melancip lalu coraknya memiliki kemiripan yakni berwarna coklat kehitaman. Corak capitnya juga sama karena berwarna putih kekuningan (19). Spesies *Uca dussumieri* termasuk ke dalam kepiting yang berhabitat di lumpur. Hal ini juga sesuai pernyataan (22) dan (23), bahwa secara umum spesies *Uca dussumieri* dapat ditemukan di daerah mangrove yang berlumpur. Spesies C1 yang diambil dari migratory birds ground at Sembilang National Park Indonesia juga berhabitat di substrat lumpur. Berdasarkan beberapa analisa ini didapatkan bahwa spesies C1 memiliki kemiripan yang sangat jelas dengan spesies *Uca dussumieri*.

Spesies C2 memiliki karapas yang berbentuk squarish atau subquadrate (2). Sepasang capitnya memiliki ukuran yang sama, cheliped spesies ini sangat panjang terutama bagian propodusnya, namun bagian dactyl memiliki ukuran tergolong pendek dan berwarna coklat kejinggaan. Warna karapasnya coklat kehitaman dengan bagian ujung anterior karapas terdapat dua gerigi yang melancip. Melalui identifikasi morfologinya, spesies C2 cukup membingungkan untuk diidentifikasi namun diduga sebagai spesies *Metaplax longipes***.** Spesies ini termasuk ke dalam family Varunidae yang dikenal sebagai family Thoracotrematan crabs (24,25). *Metaplax longipes* sebelumnya termasuk golongan Sesarminae dari family Grapsidae karena secara morfologi sangat mirip, namun berdasarkan hasil filogenetik termasuk ke Varunidae (6,7) dan oleh sebab itu *Metaplax longipes* sudah keluar dari golongan Grapsidae. *Metaplax longipes* mudah ditemukan di wilayah intertidal berlumpur kawasan mangrove (2,6,8). Berdasarkan habitat hidupnya ini dia termasuk golongan kepiting deposit feeder (26,27).

Berdasarkan identifikasi morfologi, spesies C3 diduga sebagai spesies *Metaplax disdincta*. Spesies ini memiliki bentuk karapas subquadrate (2,28). Jenis ini dikenal dengan karapas yang berbentuk kotak dan bagian posterior karapas cenderung membulat. Secara sekilas karapasnya sama dengan spesies dari kelompok Varunidae namun memiliki perbedaan pada bentuk capitnya. Hal ini disebabkan oleh spesies yang ditemukan ini berjenis kelamin betina. Ini dibuktikan dari bentuk abdomennya yaitu segitiga yang melebar. Jenis kelamin betina dari kelompok Varunidae memiliki sepasang capit yang sangat kecil dibandingkan spesies jantan (10,29,30). Berdasarkan (31) dan (32), bahwa ukuran capit kepiting betina berukuran lebih kecil dibandingkan kepiting jantan. Warna karapas spesies C3 berwarna coklat tua kehitaman dan warna capitnya berwarna hitam kemerahan dengan bagian chela berwarna keoranyean. Spesies ini berhabitat di pantai belumpur hingga berpasir (13). Spesies ini jugga termasuk kepiting yang ditemukan di kawasan mangrove (33,34). Pada beberapa kasus, spesies ini ditemukan dengan warna karapas yang lebih cerah, ini disebabkan oleh lingkungan tempat hidupnya (35,36). Karapas yang lebih gelap akan ditemukan pada daerah berlumpur sedangkan karapas yang lebih cerah akan ditemukan pada daerah susbrat cenderung berpasir (37,38).

Secara keseluruhan kepiting yang ditemukan pada penelitian ini diduga tergolong ke dalam kepiting–kepiting kecil dari family Ocypodidae dan Varunidae. Dua family juga memiliki kesamaan, sesuai yang dilaporkan oleh (39), bahwa Metaplax yang berasal dari Varunidae terkadang memiliki karakteristik perilaku yang sama dengan Ocypodidae. Secara morfologi dan cara hidupnya juga memiliki kemiripan dengan genus Macrophtalmus dari Ocypodidae. Semua spesies yang ditemukan memiliki habitat di ekosistem mangrove yang berlumpur. Kepiting memiliki peran sebagai sumber makanan bagi beberapa predator seperti burung pantai dan ikan (40–42), sedangkan di kawasan Taman Nasional Berbak-Sembilang sebagai sumber makanan bagi burung migran (43).

Scylla serrata

S. serrata termasuk dalam famili Portunidae dan kelas Krustasea dari filum Arthropoda. *S. serrata* memiliki warna karapas hijau kehitaman. Terdapat 3 pasang kaki yaitu sepasang cheliped yang digunakan untuk mencari mangsa, 3 pasang kaki jalan, dan sepasang kaki renang yang berbentuk pipih (Gambar 2).

Gambar 2. Kepiting bakau (*S. serrata*)

Taksonomi

Kingdom	: Animalia
Filum	: Arthropoda
Kelas	: Malacostraca
Ordo	: Decapoda
Family	: Portunidae
Genus	: Scylla
Spesies	: *Scylla serrata* (Forskal, 1775)

Anadara granosa

Kerang darah (*Anadara granosa*) merupakan salah satu hewan yang tergolong moluska dan termasuk ke dalam kelas bivalvia. Bivalvia merupakan kelompok hewan dengan karakteristik memiliki tubuh pipih lateral dan seluruh tubuhnya tertutup dua buah cangkang dan ukuran panjang *A. granosa* dari setiap stasiun berkisar 2-3 cm. *A. granosa* dewasa berukuran panjang 5-6 cm dan lebar 4 cm.

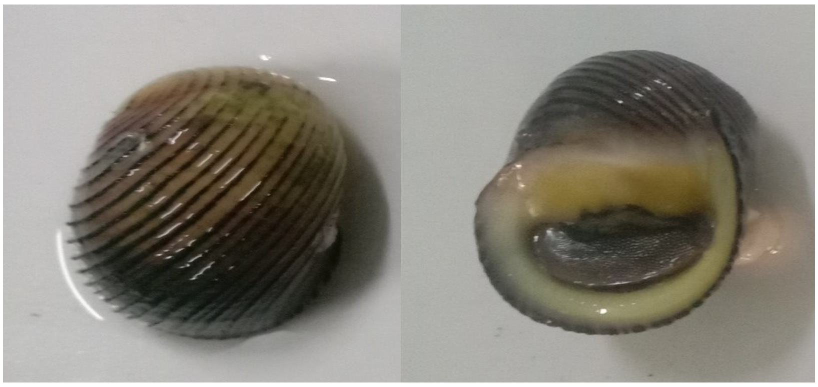
Gambar 3. Kerang darah (*Anadara granosa*)

Taksonomi

Kingdom	: Animalia
Filum	: Mollusca
Kelas	: Bivalvia
Subkelas	: Pteriomorpha
Order	: Arcoida
Famili	: Arcidae
Genus	: Anadara
Spesies	: *Anadara granosa*

Nerita balteata

Nerita balteata termasuk dalam family Neritidea dan kelas Gastropoda dari filum Moluska. *N. balteata* ditemukan pada stasiun 6 hingga 15 di kawasan mangrove yakni pada akar dan batang mangrove. *N. balteata* memiliki ciri morfologi yaitu memiliki cangkang berwarna coklat kekuningan berbentuk oval dan memiliki garis *cord* spiral berwarna hitam. Selain itu gastropoda ini memiliki cangkang yang berukuran panjang berkisar 2-3 cm dan lebar berkisar 2 cm



Gambar 4. *Nerita balteata*

Taksonomi

Kingdom	: Animalia
Filum	: Moluska
Kelas	: Gastropoda
Famili	: Neritidea
Genus	: Nerita
Spesies	: *Nerita balteata*

Cerithidea obtuse

Ciri-ciri morfologi untuk gastropoda jenis *Cerithidae obtuse* termasuk dalam famili Potamididae dan kelas Gastropoda dari filum moluska. *C. obtuse* ditemukan pada stasiun 6 hingga 10 di kawasan mangrove yakni pada akar dan batang mangrove. Ciri-ciri morfologi untuk gastropoda jenis *C. obtusa* yaitu dilihat dari cangkang yang memiliki warna coklat keputihan dan berbentuk kerucut tebal yang memiliki putaran dekstral (berputar ke arah kanan). Ukuran panjang cangkang berkisar antara 3-4,4 cm dan lebar cangkang 2-2,3 cm.

Gambar 5. *Cerithidea obtusa*

Taksonomi	
Kingdom	: Animalia
Filum	: Moluska
Kelas	: Gastropoda
Ordo	: Sorbeoconcha
Famili	: Potamididae
Genus	: Cerithidea
Spesies	: *Cerithidea obtusa*

Cerithidea cingulata

Cerithidae cingulata termasuk dalam famili Potamididae dan kelas Gastropoda dari filum Moluska. *C. cingulata* ditemukan pada stasiun 11 hingga 15 di kawasan mangrove yakni pada akar dan batang mangrove. Ciri-ciri morfologinya memiliki bentuk kerucut dan *apex* meruncing, warna cangkang coklat kekuningan atau coklat gelap, inner lip berwarna putih mengkilap.

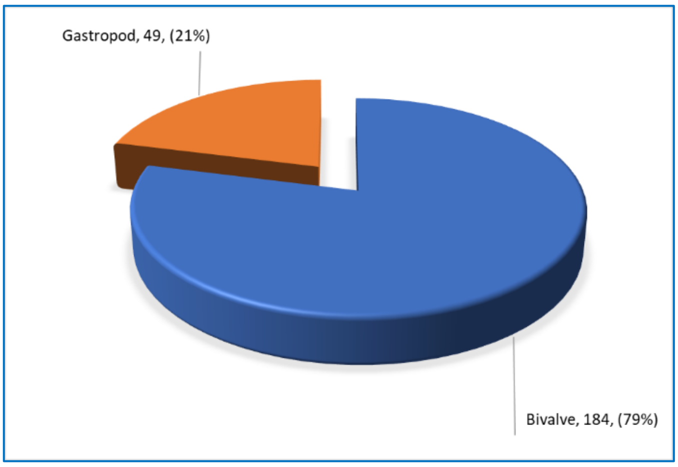
Gambar 6. *Cerithidea cingulata*

Taksonomi	
Kingdom	: Animalia
Filum	: Moluska
Kelas	: Gastropoda
Ordo	: Sorbeoconcha
Famili	: Potamididae
Genus	: Cerithidea
Spesies	: *Cerithidea cingulata*

B. Status Ekologi Moluska di Pesisir Sumatera Selatan

Hasil pengukuran kualitas perairan di kawasan pesisir Taman Nasional Berbak-Sembilang menunjukkan kondisi yang relatif stabil atau normal untuk pertumbuhan moluska. Rata-rata nilai pH perairan diperoleh pada kondisi normal 7,29 ± 0,59, serta salinitas 30,38 ± 1,30 psu. Oksigen terlarut (DO) dan suhu di semua stasiun pengamatan dikategorikan dalam kondisi baik dengan nilai rata-rata 7,78 ± 0,78 mg/L dan 29,49 ± 0,14 °C, namun kecerahan menunjukkan nilai rata-rata rendah yaitu 15,45 ± 6,18% terutama di muara. Kecepatan aliran ditemukan menurun di daerah teluk atau muara dengan nilai rata-rata 0,18 ± 0,12 m/s, sedangkan sebaran konsentrasi nitrat dan fosfat ditunjukkan relatif merata dengan rata-rata 6,08 ± 0,48 mg/L, dan 0,18 ± 0,01 mg/L.

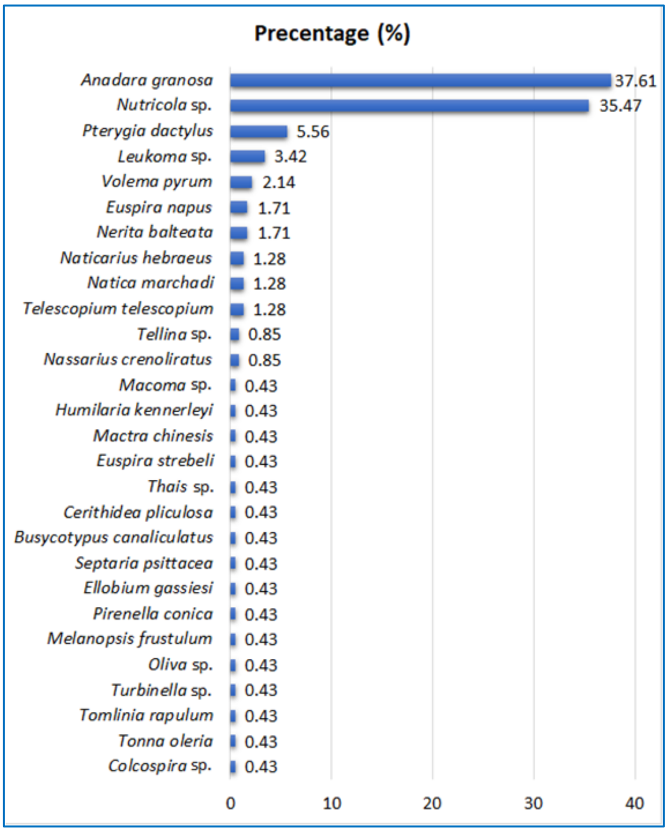
Komposisi moluska di semua stasiun pengamatan ditemukan hanya dua kelas, didominasi oleh Bivalvia 79% dan Gastropoda 21%. Sebaran kedua kelas ini tidak merata, dimana hanya terdapat pada stasiun-stasiun tertentu.



Gambar 7. Struktur komunitas Moluska di lokasi pengamatan

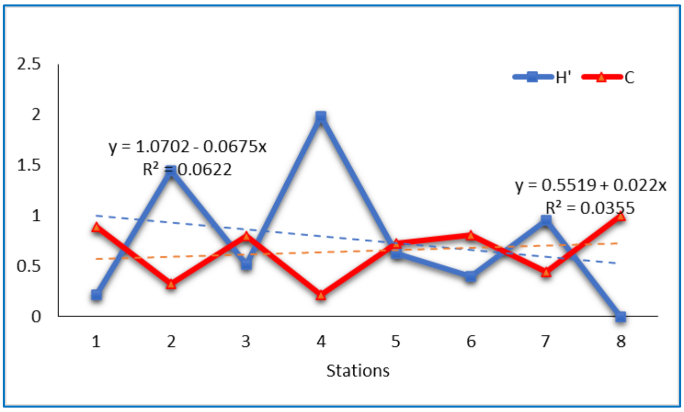
Sebanyak 28 spesies moluska yang teridentifikasi yang dinominasi oleh kelas Gastropoda dengan 21 spesies, sedangkan kelas Bivalve dengan 7 spesies. Namun, kelimpahan Bivalvia ditemukan lebih banyak daripada Gastropoda. Distribusi kelimpahan dan keanekaragaman jenis ditemukan tidak merata, seperti *Anadara granosa* yang ditemukan di hampir semua stasiun pengamatan, tetapi lebih banyak ditemukan hanya pada satu atau dua stasiun.

Nilai rata-rata keseluruhan individu moluska di lokasi pengamatan adalah 263,25 ind/m^2. Kelimpahan tertinggi terdapat pada stasiun 4 sebesar 531 ind/m^2, stasiun 3 sebesar 495 ind/m^2, stasiun 6 sebesar 333 ind/m^2, dan stasiun 5 sebesar 297 ind/m^2, sedangkan yang lainnya diambil sebagai rata-rata ditemukan. Dua jenis moluska yang ditemukan mendominasi, yaitu: *Anadara granosa* 37,61% dan *Nutricola* sp. 35,47%, keduanya berasal dari kelas Bivalvia, berbeda dengan kelimpahan kelas Gastropoda yang didominasi oleh *Pterygia dactylus* 5,56% dan *Volema pyrum* 2,14%. Selain itu, sebaran kelas Bivalvia ternyata lebih merata dibandingkan Gastropoda.



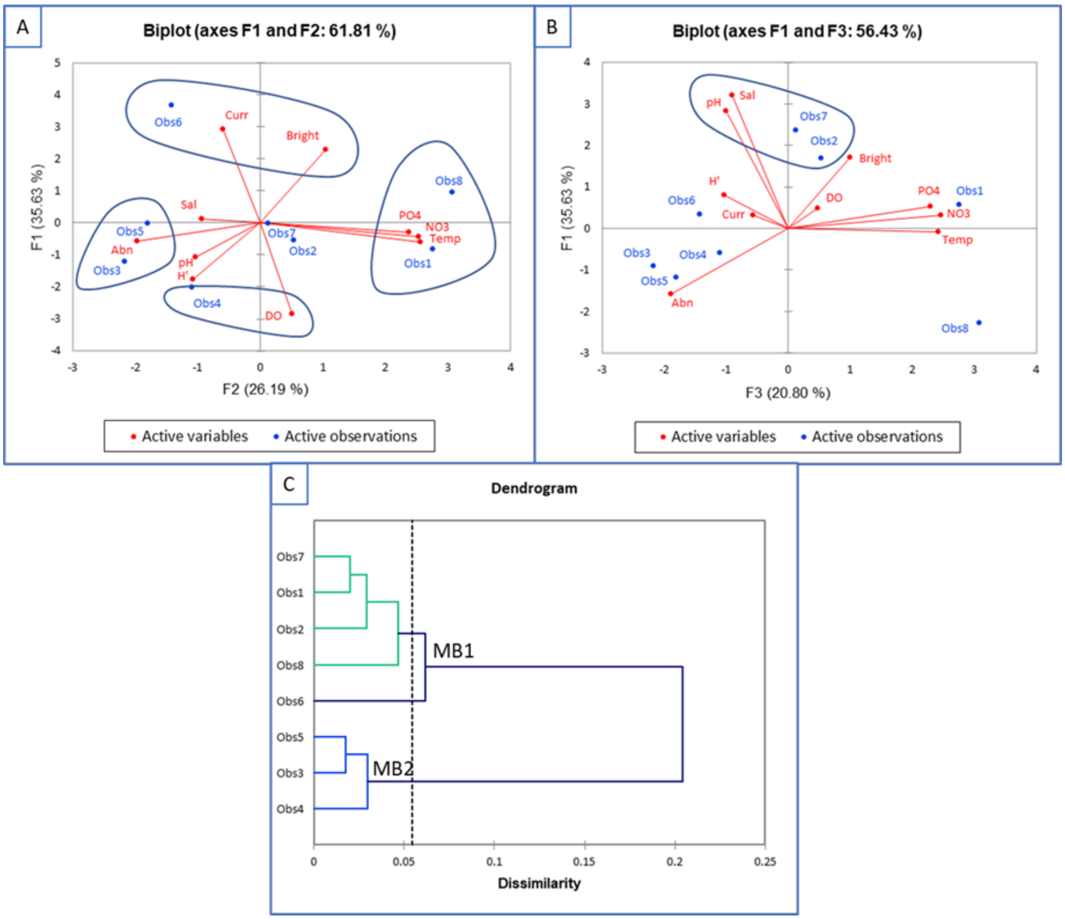
Gambar 8. Persentase spesies moluska

Mengingat keragaman spesies, indeks Shannon-Wiener (H') semuanya menurun secara signifikan di hampir semua stasiun pengamatan kategori rendah (Stasiun 1, 3, 5, 6, 7, dan 8), kecuali ada dua stasiun dalam kondisi sedang. kategori (Stasiun 2 dan 4). Hal ini juga didukung oleh nilai indeks Simpson (C), dimana dominasi spesies terjadi hampir di semua lokasi.



Gambar 9. Indeks Keanekaragaman Moluska di Taman Nasional Berbak-Sembilang

Hasil hubungan parameter kualitas air dengan kelimpahan dan keanekaragaman moluska di lokasi penelitian diperoleh Eigenvalues Kumulatif 82,61%, terbentuk lima kelompok yaitu: empat kelompok terbentuk pada sumbu F1 dan F2, sedangkan yang lainnya terbentuk pada sumbu F3 . Selain itu, kemiripan antar stasiun pengamatan dibentuk oleh dua cluster berkode MB1 dan MB2.



Gambar 10. Hubungan antara parameter kualitas air dengan kelimpahan dan keanekaragaman moluska, (a) sumbu F1 dan F2; (b) sumbu F3; (c) *Dendrogram dissimilarity*

Hasil analisis kemiripan yang dihitung dengan indeks dissimilaritas Bray-Curtis (Gambar 10c) menunjukkan bahwa sebaran kelimpahan dan keragaman moluska hampir sama, membentuk dua cluster (MB1 dan MB2). Nilai kesamaan rata-rata sebesar 83,74%. Klaster MB1 terbentuk pada stasiun 1, 2, 6, 7, dan 8 yang berada di pantai terbuka. Cluster ini dicirikan oleh suhu, salinitas, pH, kecerahan nutrisi, dan arus air yang lebih tinggi. Hal ini diduga karena pengaruh kuat wilayah massa air laut Selat Melaka dan Laut Cina Selatan. Klaster MB2 dibentuk oleh stasiun 3, 4, dan 5 yang terletak di muara muara sungai, ditandai dengan oksigen terlarut dan kelimpahan moluska yang lebih tinggi dibandingkan lokasi lain. Fluktuasi parameter kualitas air yang terus menerus diduga berdampak pada dominasi beberapa spesies di setiap stasiun. Kedua klaster tersebut menggambarkan bahwa kelimpahan dan keanekaragaman moluska di garis pantai lindung TNBS sangat dipengaruhi oleh perubahan parameter kualitas air.

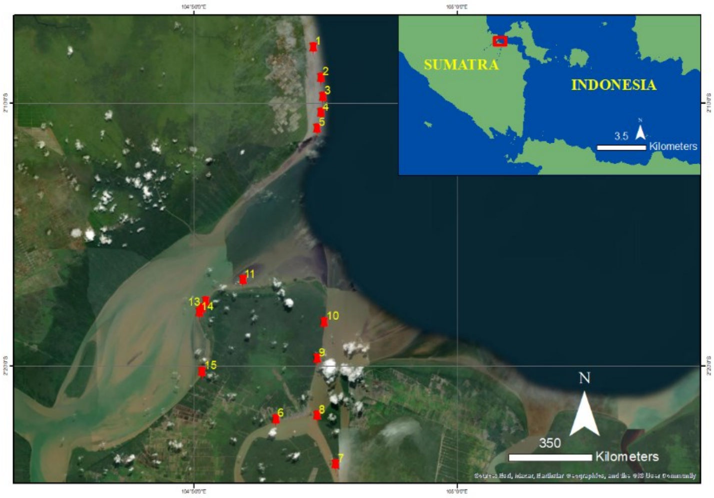
Terdapat 28 spesies moluska yang ditemukan di garis pantai lindung TNBS, yang dikelompokkan menjadi dua kelas, yaitu Bivalve 79% dengan 7 spesies, dan Gastropoda 21% dengan 27 spesies. Komposisi individu kelas Bivalvia lebih dominan dibandingkan dengan Gastropoda, meskipun jumlah spesiesnya lebih sedikit. Bivalvia memiliki kemampuan toleransi yang tinggi terhadap perubahan parameter lingkungan (44). Komposisi ini juga telah dilaporkan di pantai barat India (45), di estuari dari Sungai Gharehsou (46), di perkebunan bakau dan dua asosiasi alami Khanh Hoa, Vietnam (47). Berbeda dengan yang diberitakan bahwa Polychaeta lebih dominan di Muara Sungai Yangtze dan Pulau Batam, Indonesia (48), Gastropoda ditemukan dominan di Muara Musi (49), Gastropoda juga dominan di telaga parut kecamatan Pasuruan Jawa Timur (50), Gastropoda mendominasi Mumbai, pantai barat India (51). Hal ini menunjukkan bahwa persebaran individu kedua kelas moluska tersebut sangat bergantung pada habitatnya.

Kelimpahan moluska ditemukan cukup tinggi, yang meningkat secara signifikan di daerah estuari dibandingkan dengan daerah pesisir terbuka. Hal ini diduga dipengaruhi oleh keluarnya massa air dari tanah yang membawa lebih banyak bahan tersuspensi dan unsur hara. Selain itu pertemuan massa air menimbulkan daerah percampuran yang berdampak pada peningkatan kesuburan perairan. Kondisi ini sangat cocok untuk pertumbuhan dan reproduksi komunitas moluska sebagai biota sessile akuatik. Kelimpahan total ini lebih tinggi dari yang dilaporkan oleh (52–62).

C. Bioakumulasi Logam Berat Pada Biota Bentik Dari Pesisir Sumatera Selatan

Akumulasi Logam Berat pada Komunitas Bentik

Pengambilan sampel biota bentik untuk menganalisa kandungan logam berat disajikan pada Gambar 11.



Gambar 11. Lokasi *sampling*

Kandungan logam berat berdasarkan hasil pengukuran menggunakan AAS (*Atomic Absorption Spectroscopy*) Tipe AA 7000 pada tiga variabel disajikan pada Tabel 1.

Tabel 1. Kandungan logam berat

Sampel	**Stasiun**	**Logam Berat**			
		Pb	**Baku Mutu Pb**	**Cu**	**Baku Mutu Cu**
	1	0,400		TTD	
	2	0,429		TTD	
	3	0,434		TTD	
	4	0,333		TTD	
	5	0,302		TTD	
	6	0,008		TTD	
	7	TTD		TTD	
Air (mg/l)	8	TTD	0,008*	TTD	0,008*
	9	TTD		TTD	
	10	TTD		TTD	
	11	0,053		TTD	
	12	0,105		TTD	
	13	0,112		TTD	
	14	0,625		TTD	
	15	0,085		TTD	
	1	8,680		2,738	
	2	8,458		2,039	
	3	8,730		2,189	
	4	5,083		3,463	
	5	6,716		1,930	
	6	4,329		3,296	
	7	3,523		2, 357	
Sedimen (mg/kg)	8	3,989	50**	2,822	65**
	9	3,921		2,451	
	10	1,261		0,193	
	11	9,312		12,614	
	12	11,070		10,510	
	13	9,656		12,496	
	14	7,440		19,300	
	15	9,454		17,070	

Sampel	Stasiun	Logam Berat			
		Pb	Baku Mutu Pb	Cu	Baku Mutu Cu
	1	0,0026		0,0014	
	2	0,0041		0,0024	
	3	0,0042		0,0021	
	4	0,0029		0,0022	
	5	0,0044		0,0021	
	6	0,0010		0,0010	
***Neoleanira tetragona* (mg/kg)**	7	0,0004		0,0004	
	8	0,0005	0,12***	0,0021	3,28***
	9	0,0008		0,0008	
	10	0,0020		0,0016	
	11	0,0013		0,0003	
	12	0,0001		0,0009	
	13	0,0037		0,0022	
	14	TTD		0,0006	
	15	0,0008		0,0014	
	1	0,003		0,004	
	2	0,001		0,011	
	3	0		0,004	
	4	0,003		0,013	
	5	0,002		0,009	
	6	-		-	
***Anadara granosa* (mg/kg)**	7	-		-	
	8	-	0,12***	-	3,28***
	9	-		-	
	10	-		-	
	11	-		-	
	12	-		-	
	13	-		-	
	14	-		-	
	15	-		-	
	1	-		-	
	2	-		-	
	3	-		-	
	4	-		-	
	5	-		-	
	6	0,004		0,005	
***Nerita balteata* (mg/kg)**	7	0,004		0,005	
	8	0,003	0,12***	0,004	3,28***
	9	0,002		0,024	
	10	0,002		0,023	
	11	0,002		0,004	
	12	0,002		0,003	
	13	0,004		0,018	
	14	0,003		0,02	
	15	0,002		0,02	
	1	-		-	
	2	-		-	
	3	-		-	
	4	-		-	
	5	-		-	
***Cerithidea obtusa* (mg/kg)**	6	0,002		0,005	
	7	0,002	0,12***	0,005	3,28***
	8	0,003		0,016	
	9	0,003		0,012	
	10	0,003		0,009	
	11	-		-	
	12	-		-	
	13	-		-	

Sampel	Stasiun	Logam Berat			
		Pb	Baku Mutu Pb	Cu	Baku Mutu Cu
	14	-		-	
	15	-		-	
Cerithidea cingulata (mg/kg)	1	-	0,12***	-	3,28***
	2	-		-	
	3	-		-	
	4	-		-	
	5	-		-	
	6	-		-	
	7	-		-	
	8	-		-	
	9	-		-	
	10	-		-	
	11	0,001		0,021	
	12	0,001		0,026	
	13	0,001		0,018	
	14	0,004		0,026	
	15	0,004		0,022	
***Scylla serrata* (mg/kg)**	1	-	0,12***	-	3,28***
	2	-		-	
	3	-		-	
	4	-		-	
	5	-		-	
	6	-		-	
	7	-		-	
	8	-		-	
	9	-		-	
	10	-		-	
	11	0,0002		0,031	
	12	0,0001		0,055	
	13	TTD		0,080	
	14	0,0021		0,030	
	15	0,0008		0,062	

Keterangan, TTD : Tidak terdeteksi alat AAS

* : Kepmen LH. No.51 Tahun 2004

** : ANZECC, 2013

Konsentrasi logam berat Pb di air dari hasil pengukuran di laboratorium berkisar TTD – 0,625 mg/L. Konsentrasi terendah pada stasiun 7, 8, 9 dan 10 dan tertinggi pada stasiun 14. Sedangkan Nilai konsentrasi logam berat Cu yang didapatkan tidak terdeteksi oleh AAS. Konsentrasi logam berat Pb pada sedimen berdasarkan hasil pengukuran didapatkan berkisar 1,261 – 11,070 mg/kg . Konsentrasi terendah terdapat pada stasiun 10 dan stasiun 12. Adapun nilai konsentrasi logam berat Cu di sedimen didapatkan berkisar antara 1,930 - 19,30 mg/kg. Konsentrasi logam berat Pb dalam polychaeta memiliki kisaran TTD - 0,0044 mg/kg sedangkan nilai konsentrasi logam berat Cu adalah berkisar antara 0,0003 -0,0024 mg/kg.

Konsentrasi logam berat Pb dan Cu pada *A. granosa* yang ditemukan di stasiun 1 sampai 5 secara berurutan berkisar 0 - 0,003 mg/kg (Pb) dan 0,004-0,013 mg/kg (Cu). Konsentrasi logam berat Pb dan Cu pada *N. balteata* yang ditemukan di stasiun 6 sampai 15 secara berurutan berkisar 0,002 – 0,004 mg/kg (Pb) dan 0,003 – 0,024 mg/kg (Cu). Konsentrasi logam berat Pb dan Cu pada *C. obtusa* yang ditemukan di stasiun 6 sampai 10 secara berurutan berkisar 0,002 – 0,003 mg/kg (Pb) dan 0,005 – 0,016 mg/kg (Cu). Konsentrasi logam berat Pb dan Cu pada *C. cingulata* yang ditemukan di stasiun 11 sampai 15 secara berurutan berkisar 0,001 – 0,004 mg/kg (Pb) dan 0,018 – 0,026 mg/kg (Cu).

Konsentrasi logam berat Pb dan Cu dalam polychaeta yang didapatkan tidak melebihi baku mutu yang ditetapkan *International Atomic Energy Agency* Tahun 2003, dimana baku mutu logam berat Pb bernilai 0,12 mg/kg dan untuk Cu bernilai 3,28 mg/kg. Konsentrasi logam berat dapat bertambah tergantung dengan kondisi lingkungan perairan (63). Logam berat dapat berpindah ke dalam tubuh organisme melalui rantai makanan (64). Selain melalui rantai makanan, logam berat bisa masuk ke dalam tubuh polychaeta melalui kebiasaan dan pola makan dari polychaeta itu sendiri.

Konsentrasi logam Cu dan Pb pada *A. granosa* yang ditemukan di lokasi penelitian tergolong lebih rendah dibandingkan beberapa penelitian lain seperti pada penelitian (65) dan (66) yang mana juga meneliti kandungan logam berat yang terdapat pada jaringan bivalvia yakni berkisar 1,34 ± 0,59 mg/kg dan 2,45 mg/kg untuk Cu serta 0,04 ± 0,01 mg/kg dan 2,97 mg/kg untuk Pb. Kandungan logam berat akan terus meningkat seiring dengan lamanya kerang hidup di lingkungan sedimen karena sifatnya yaitu *filter feeder*. Menurut (67) juga konsentrasi logam berat pada sedimen juga mempengaruhi tinggi rendahnya konsentrasi logam berat pada kerang darah.

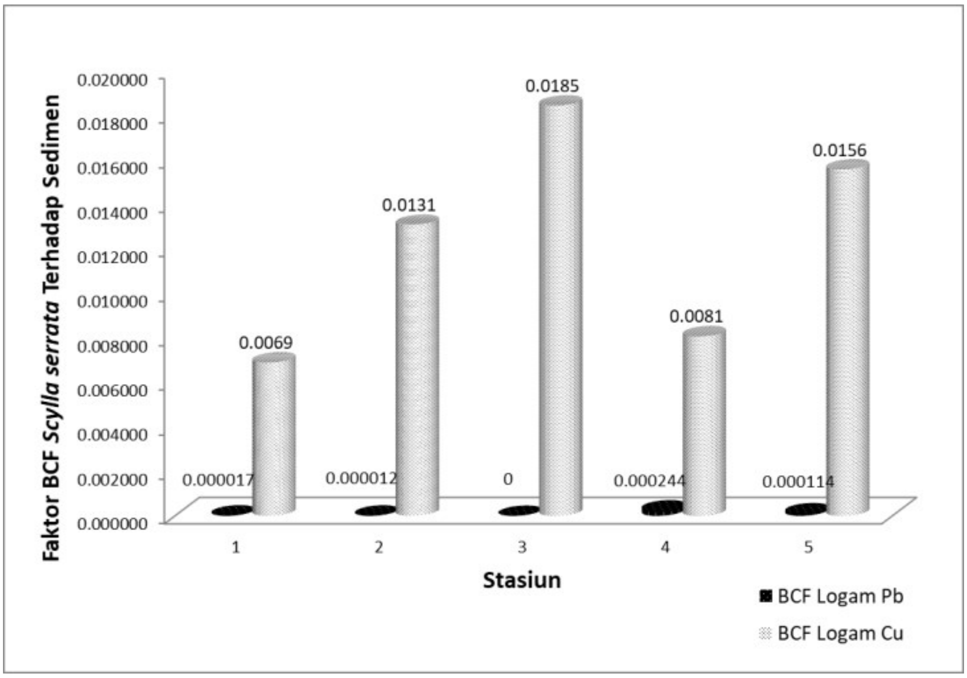
N. balteata, C. cingulata dan *C. obtuse* ditemukan di kawasan mangrove yakni pada akar dan batang mangrove. Kemampuan setiap masing-masing spesies gastropoda dalam mengatur dan mengakumulasi logam berat dikaitkan dengan fisiologi pencernaan pada spesies dan laju penyerapan logam berat oleh organisme itu sendiri. Perbedaan konsentrasi logam berat juga dipengaruhi oleh tingkat polusi, laju metabolisme, berat badan dan umur dari gastropoda itu sendiri (68). Ditemukan nilai kadar Cu pada *N. lineata* (2,80 - 4,40 mg/g) dan Pb (38.55 - 53.35 mg/g) dari zona intertidal. Berdasarkan penelitian (69) ditemukan pula nilai Cu (0,10 - 0,84 mg/g) dan Pb (0,03 - 0,08 mg/g) pada *C. Cingulata*.

Nilai konsentrasi logam berat Pb dan Cu pada *A. granosa, N. balteata*, *C. cingulata* dan *C. obtuse* menunjukkan bahwa nilainya masih dibawah baku mutu yang ditelah ditetapkan. Baku mutu yang logam berat untuk moluska mengacu pada FAO (1983) dimana untuk Pb (1,5 mg/kg) dan Cu (10 mg/kg). Artinya keempat biota ini tercemar logam berat Pb dan Cu dengan kadar yang masih aman untuk dikonsumsi oleh masyarakat. Keempat biota ini termasuk ke dalam biota konsumsi dan memiliki baku mutu kandungan logam berat Cu sebesar 20 ppm (Rahma *et al*. 2019). Hubungan antara parameter kualitas air dengan konsentrasi logam berat pada air, sedimen dan biota makrobentos ditunjukkan oleh suhu, salinitas dan pH yang ditentukan oleh jenis biota yang dianalisis dan lokasi stasiun.

Makrozoobentos memiliki sifat *filter feeder* yang memungkinkan dapat menyerap sejumlah logam berat yang berada pada perairan. Perbedaan kandungan logam berat dalam biota menurut (49), dapat disebabkan oleh beberapa faktor diantaranya perbedaan jenis spesies, kemampuan fisiologis organisme dan kondisi lingkungannya. *Neoleanira tetragona* di lokasi penelitian memiliki kandungan logam berat Pb dan Cu yang rendah. Hal ini dapat disebabkan karena kondisi lingkungan dan konsentrasi logam berat dalam sedimen juga tergolong rendah.

***Bioconcentration Factor* (BCF)**

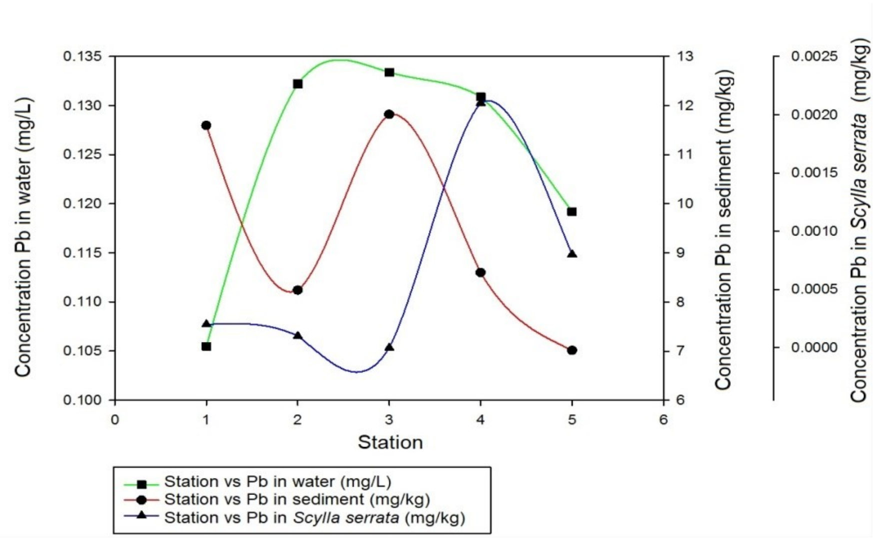
Faktor biokonsentrasi digunakan untuk mengetahui tingkat akumulasi logam berat Pb dan Cu pada *S. serrata* terhadap logam berat air dan sedimen (Gambar 12). Pada penelitian ini, BCF *S. serrata* terhadap air untuk logam tidak dapat ditentukan, karena logam berat Cu pada air tidak terdeteksi. Berdasarkan hasil perhitungan nilai BCF logam Pb *S. serrata* terhadap sedimen berkisar 0,000012 – 0,000244. Sedangkan nilai BCF logam Cu *S. serrata* terhadap sedimen berkisar 0,0069 – 0,0185.



Gambar 12. Faktor Biokonsentrasi (BCF) Logam Berat Pb dan Cu

Distribusi Logam Berat pada Air, Sediment, dan *Scylla Serrata*

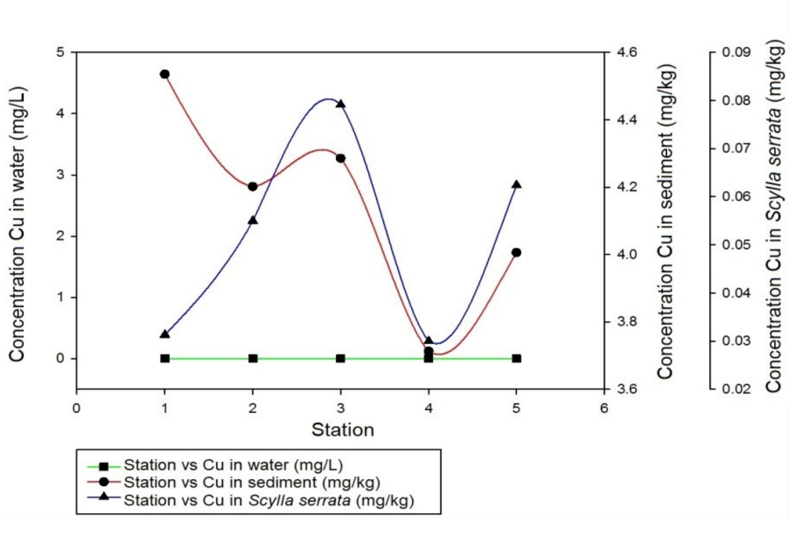
Distribusi logam berat Pb pada air, sedimen, dan *Scylla serrata* menunjukkan sebaran yang fluktuatif (Gambar 13). Konsentrasi logam berat tertinggi terdapat pada sedimen di seluruh stasiun. Kemudian diikuti dengan konsentrasi Pb pada air dan konsentrasi Pb terendah terdapat pada *Scylla serrata*.



Gambar 13. Distribusi Logam Berat Pb

Stasiun 1 menunjukkan hasil yang bervariasi dimana logam berat Pb pada sedimen menunjukkan nilai yang tinggi, sedangkan pada air dan *Scylla serrata* menunjukkan nilai yang rendah dibandingkan dengan stasiun lain. Logam berat Pb sedimen dan *Scylla serrata* memiliki pola yang menurun, sedangkan pada air memiliki pola yang meningkat. Stasiun 3 menunjukkan pola logam berat Pb air dan *Scylla serrata* cenderung sama dengan stasiun 2, sedangkan pada sedimen memiliki pola meningkat dengan signifikan. Logam berat Pb pada air dan sedimen di stasiun 4 memiliki pola menurun, sedangkan pada *Scylla serrata* memiliki pola yang meningkat dengan signifikan. Pada stasiun 5 menunjukkan logam berat Pb pada air, sedimen, dan *Scylla serrata* memiliki pola yang sama yaitu menurun.

Hasil distribusi logam berat Cu pada pada sedimen tertinggi di seluruh stasiun. Kemudian diikuti dengan konsentrasi Cu pada *Scylla serrata*, sedangkan pada air tidak terdeteksi (Gambar 14).

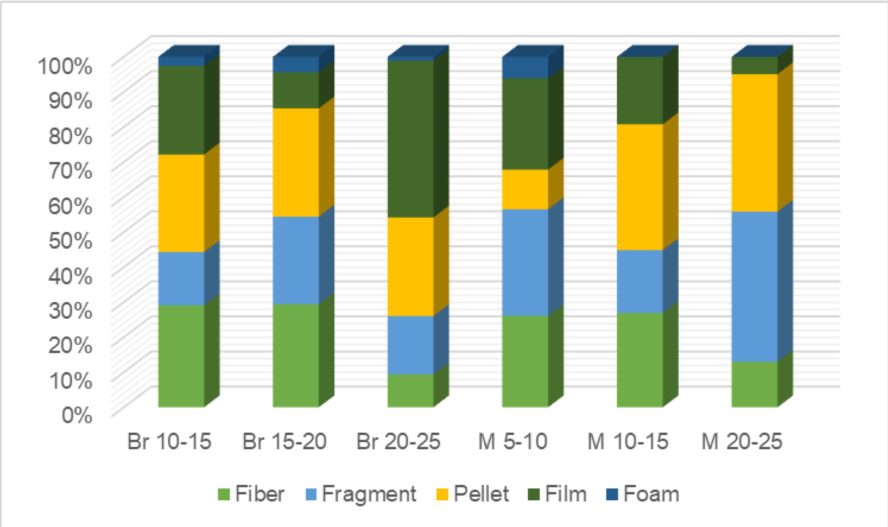


Gambar 14. Distribusi Logam Berat Cu

Konsentrasi Cu sedimen dan *Scylla serrata* pada stasiun 1 menunjukkan pola yang berbeda, konsentrasi Cu pada sedimen stasiun 1 menunjukkan konsentrasi tertinggi dibandingkan dengan stasiun lainnya, sedangkan pada *Scylla serrata* menunjukkan konsentrasi yang rendah dibandingkan dengan stasiun lainnya. Pada stasiun 2 konsentrasi Cu pada sedimen memiliki pola yang menurun, sedangkan pada *Scylla serrata* memiliki pola yang meningkat. Pada stasiun 3, 4, dan 5 menunjukkan pola yang sama antara sedimen dan *Scylla serrata* dimana pada stasiun 3 mengalami kenaikan, stasiun 4 mengalami penurunan, dan pada stasiun 5 mengalami kenaikan.

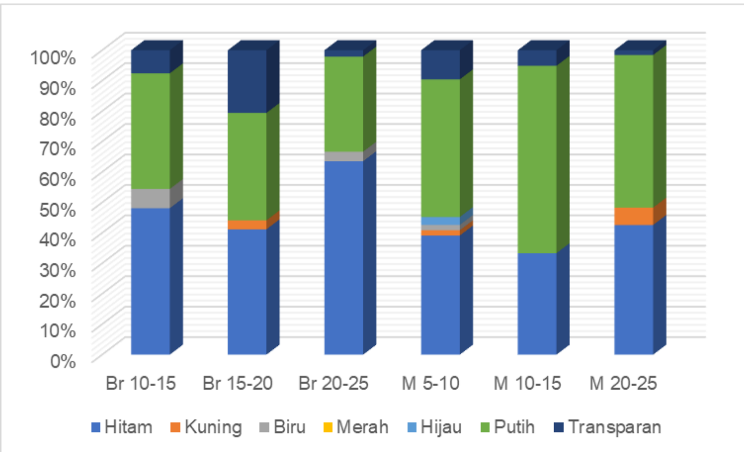
D. Bioakumulasi Mikroplastik Pada Biota Bentik Dari Pesisir Sumatera Selatan

Biota yang dianalisis kandungan mikroplastik (MPs) yaitu kerang *A. granosa*. Pemilihan ini didasarkan oleh perannya yang menjadi salah satu komoditas laut terbesar di Sumatera Selatan sedangkan perairannya diyakini menjadi sumber masuknya bahan pencemar MPs karena intensitas aktivitas antropogenik tinggi di perairan. Lokasi pengambilan sampel di kawasan perairan Sungai Barong dan Sungai Musi. Sampel diukur berdasarkan ukuran yang kemudian dibagi menjadi tiga kategori ukuran (kecil, sedang, besar).



Gambar 15. Karakterisasi mikroplastik berdasarkan jenis

Berdasarkan Gambar 15, mikroplastik yang ditemukan meliputi 5 jenis yaitu fiber, fragmen, pellet, film, dan foam. MPs jenis foam menjadi yang paling sedikit ditemukan diantara jenis lainnya. MPs fiber ditemukan pada kisaran 9% - 29%, MPs fragment ditemukan pada kisaran 15% - 43%, MPs pellet berkisar 11% - 39%, MPs film berkisar antara 5% - 45%, dan MPs foam berkisar 0% - 6%.



Gambar 16. Karakterisasi mikroplastik berdasarkan warna

Berdasarkan Gambar 16, mikroplastik yang ditemukan meliputi 7 warna yaitu hitam, kuning, biru, merah, hijau, putih, dan transparan. MPs hitam dan putih sangat dominan ditemukan di semua sampel dengan lebih dari 30%. MPs hitam ditemukan pada kisaran 33% - 64% sementara MPs putih berada ditemukan pada kisaran 31% - 62%. MPs transparan berkisar 2% - 21%, MPs Biru dan Kuning berkisar antara 0% - 6%, dan MPs hijau berkisar 0% - 3%.

Spesies *A. granosa* hidup di dasar perairan dan sebagian besar dihabiskan dengan mencari makan di permukaan subsrat (70,71). Terkait dengan perilakunya tersebut, maka terdapat hubungan antara kelimpahan MPs yang mengendap di dasar perairan dengan total bioakumulasi MPs pada organisme makrozoobentos ini. MPs dapat terakumulasi ke dalam tubuh organisme melalui saluran makannya lalu menyebar ke seluruh jaringan tubuh (72,73). Intensitas paparan yang tinggi akan menyebabkan gangguan kesehatan bahkan kematian pada organisme. Dampak jangka panjangnya yaitu hilangnya keseimbangan sistem ekologi sedangkan partikel MPs terus berpindah dari satu organisme ke organisme lain melalui proses biomagnifikasi.

Penilaian potensi MPs beracun dapat dilakukan dalam dua perspektif sekaligus yakni penilaian kuantitatif MPs dan penilaian kuantitatif antioksidan pada organisme makrozoobentos. Keduanya memiliki hubungan yang linier, bahwa semakin tinggi tingkat paparan MPs maka level antioksidannya juga semakin kuat. Senyawa-senyawa bioaktif yang berhasil teridentifikasi bersifat antioksidan dalam respon fisiologis organisme yaitu jenis senyawa flavonoid, senyawa fenolat, peroksidase dan senyawa protein (74).

D. **STATUS LUARAN**: Tuliskan jenis, identitas dan status ketercapaian setiap luaran wajib dan luaran tambahan (jika ada) yang dijanjikan. Jenis luaran dapat berupa publikasi, perolehan kekayaan intelektual, hasil pengujian atau luaran lainnya yang telah dijanjikan pada proposal. Uraian status luaran harus didukung dengan bukti kemajuan ketercapaian luaran sesuai dengan luaran yang dijanjikan. Lengkapi isian jenis luaran yang dijanjikan serta mengunggah bukti dokumen ketercapaian luaran wajib dan luaran tambahan melalui BIMA.

Status Luaran Penelitian Tahun 2022
Jenis : Jurnal Internasional Bereputasi (Luaran Wajib)
Identitas : International Journal of Conservation Science (ISSN: 2067-533X) – Terindeks Scopus Q2
Status : Published

Jenis : Jurnal Internasional Bereputasi (Luaran Tambahan)
Identitas : Regional Studies in Marine Science (ISSN: 2352-4855) – Scopus Q2
Status : Submit

E. **PERAN MITRA:** Tuliskan realisasi kerjasama dan kontribusi Mitra baik *in-kind* maupun *in-cash* (untuk Penelitian Terapan, Penelitian Pengembangan, PTUPT, PPUPT serta KRUPT). Bukti pendukung realisasi kerjasama dan realisasi kontribusi mitra dilaporkan sesuai dengan kondisi yang sebenarnya. Bukti dokumen realisasi kerjasama dengan Mitra diunggah melalui BIMA.

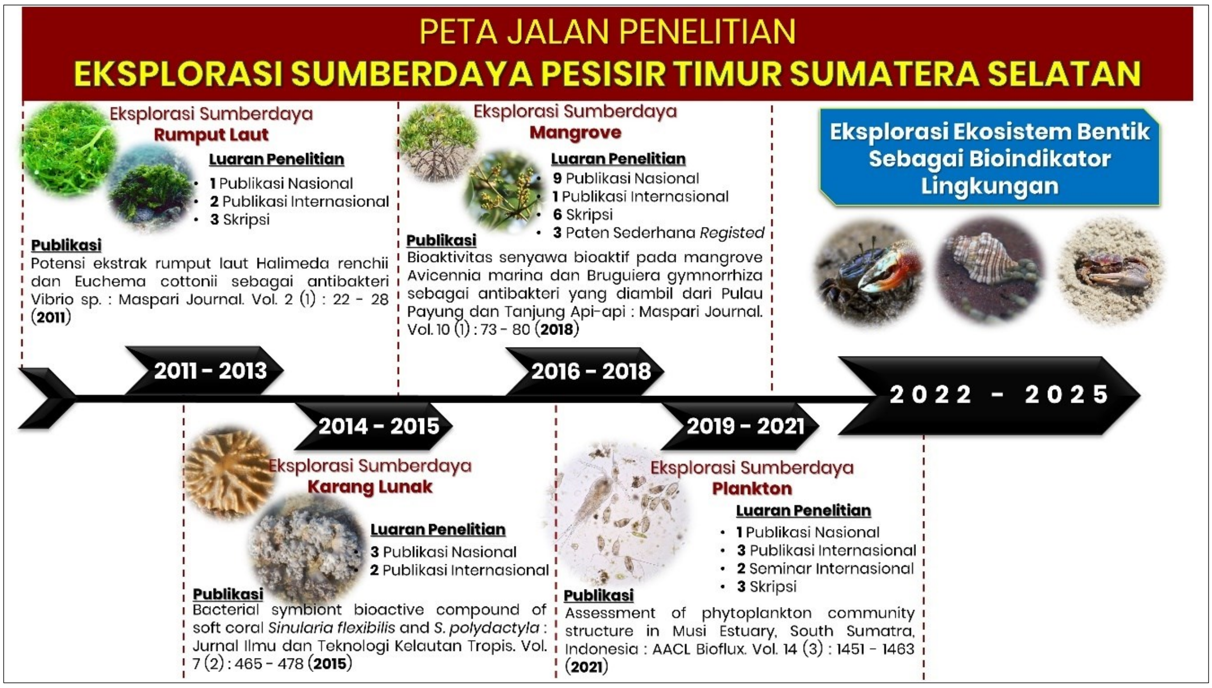
-

F. **KENDALA PELAKSANAAN PENELITIAN**: Tuliskan kesulitan atau hambatan yang dihadapi selama melakukan penelitian dan mencapai luaran yang dijanjikan, termasuk penjelasan jika pelaksanaan penelitian dan luaran penelitian tidak sesuai dengan yang direncanakan atau dijanjikan.

Penelitian ini melibatkan beberapa mahasiswa S1 dalam pengerjaannya sekaligus menjadi studi tugas akhir mereka. Keterlibatan secara langsung tersebut membutuhkan waktu yang cukup panjang secara administrasinya sehingga jalannya penelitian ini sedikit terlambat terutama pada topik tekanan mikroplastik pada ekosistem bentik. Namun seiring berjalannya waktu, keterlambatan jadwal tersebut tetap dikejar sesuai target perminggunya. Secara umum, pelaksanaan tiap tahap penelitian tidak memiliki hambatan yang signifikan, namun tim telah berusaha secara optimal dalam mencapai target capaian.

G. **RENCANA TAHAPAN SELANJUTNYA:** Tuliskan dan uraikan rencana penelitian di tahun berikutnya berdasarkan indikator luaran yang telah dicapai, rencana realisasi luaran wajib yang dijanjikan dan tambahan (jika ada) di tahun berikutnya serta *roadmap* penelitian keseluruhan. Pada bagian ini diperbolehkan untuk melengkapi penjelasan dari setiap tahapan dalam metoda yang akan direncanakan termasuk jadwal berkaitan dengan strategi untuk mencapai luaran seperti yang telah dijanjikan dalam proposal. Jika diperlukan, penjelasan dapat juga dilengkapi dengan gambar, tabel, diagram, serta pustaka yang relevan. Jika laporan kemajuan merupakan laporan pelaksanaan tahun terakhir, pada bagian ini dapat dituliskan rencana penyelesaian target yang belum tercapai.

Semua data yang dikumpulkan akan dilakukan analisis data sebagai bagian dari pengerjaan penelitian ini untuk mendukung tujuan besar Peta Jalan Penelitian. Analisa terhadap data akan dilakukan oleh semua anggota tim untuk menemukan fenomena-fenomena terbaru yang mendukung kebaharuan ilmu pengetahuan sebagai salah satu unsur yang wajib ada dalam penulisan artikel ilmiah khususnya pada jurnal-jurnal internasional bereputasi yang menjadi luaran penelitian untuk tahun pertama dan kedua serta buku untuk tahun kedua.



Gambar 9. Peta jalan penelitian

Kegiatan penelitian yang dilakukan telah menghasilkan data-data yang mendukung tujuan besar Peta Jalan Penelitian yaitu Eksplorasi Ekosistem Bentik sebagai Bioindikator Lingkungan (Gambar 9). Selanjutnya, kajian tersebut akan bermanfaat pada pengembangan bidang *Marine Bioprospecting*. Hasil penelitian tersebut diharapkan akan diimplementasikan sebagai sebuah produk yang bermanfaat bagi sosial ekonomi masyarakat dan pengembangan produk kesehatan berbasis sumber daya alam dan pesisir. Sejalan dengan kegiatan penelitian yang terus berlanjut, artikel hasil penelitian akan terus diproses untuk publikasi sebagai luaran penelitian pada tahun yang sama dengan tahun kegiatan dan tahun berikutnya.

H. DAFTAR PUSTAKA: Penyusunan Daftar Pustaka berdasarkan sistem nomor sesuai dengan urutan pengutipan. Hanya pustaka yang disitasi pada laporan kemajuan yang dicantumkan dalam Daftar Pustaka.

1. Mangale VY, Kulkarni BG. Morphological Study of Fiddler Crabs in Mumbai Region. Adv Biores. 2013;4(3):86–91.
2. Shih H-T, Hsu J-W, Wong KJH, Ng NK. Review of the mudflat varunid crab genus Metaplax (Crustacea, Brachyura, Varunidae) from East Asia and northern Vietnam. Zookeys. 2019;877:1–29.
3. Shih H-T, Lee J-H, Ho P-H, Liu H-C, Wang C-H, Suzuki H, Teng S-J. Species diversity of fiddler crabs, genus Uca Leach, 1814 (Crustacea: Ocypodidae), from Taiwan and adjacent islands, with notes on the Japanese species. Zootaxa. 2016;4083(1):57–82.

4. Shukla M, Patel B, Trivedi J, Vachhrajani K. Brachyuran crabs diversity of Mahi and Dhadhar estuaries, Gujarat, India. Res J Mar Sci. 2013;2321:1296.

5. Rianta P, Ernawati W, Chen G, Chen S. Diversity and abundance of mangrove fiddle crabs, genus Uca (Decapoda, Ocypodidae) at a mangrove in Kema, North Sulawesi, Indonesia. Acta Oceanol Sin. 2018;37(12):92–96.

6. Liu Y, Yang T-T, Xin Z-Z, Liu Q-N, Zhang D-Z, Tang B-P. The complete mitochondrial genome sequence of Metaplax longipes (Grapsoidea: Varunidae). Mitochondrial DNA Part B. 2019;4(1):1280–1282.

7. Chen J, Xing Y, Yao W, Xu X, Zhang C, Zhang Z, Liu Q. Phylomitogenomics reconfirm the phylogenetic position of the genus Metaplax inferred from the two grapsid crabs (Decapoda: Brachyura: Grapsoidea). PLoS One. 2019;14(1):e0210763.

8. Chen P, Zhang Y, Zhu X, Lu C. Distribution of crabs along a habitat gradient on the Yellow Sea coast after Spartina alterniflora invasion. PeerJ. 2019;7:e6775.

9. Marin IN. New data on the distribution of hairy-clawed shore crabs of the genus Hemigrapsus (Decapoda: Varunidae) along the Russian mainland coast of the Sea of Japan. Russ J Mar Biol. 2013;39(4):301–305.

10. Wójcik D, Normant M, Dmochowska B, Fowler A. Impact of Chinese mitten crab Eriocheir sinensis on blue mussel Mytilus edulis trossulus–laboratory studies of claw strength, handling behavior, consumption rate, and size selective predation. Oceanologia. 2015;57(3):263–270.

11. Webster J, Clark P, Morritt D. Laboratory based feeding behaviour of the Chinese mitten crab, Eriocheir sinensis (Crustacea: Decapoda: Brachyura: Varunidae): fish egg consumption (De Haan, 1835). Aquat Invasions. 2015;10(3):313–326.

12. Davie P, Xuan N. A new species of Metaplax (Crustacea: Brachyura: Varunidae: Cyclograpsinae) from Vietnam. Raffles Bull Zool. 2003;51:379–386.

13. Mohanty B, Nayak A, Dash B, Rout SS, Charan Kumar B, Patnaik L, Dev Roy MK, Raman A, Raut D. Biodiversity and ecological considerations of brachyuran crabs (Crustacea: Decapoda) from Devi estuary–mangrove region on the east coast of India. Reg Stud Mar Sci. 2019;32:100865.

14. Murniati D. Pola Dominansi Capit Pada Uca spp. (Decapoda: Ocypodidae). Berk Hayati. 2010;16:15–20.

15. Murniati D, Afriadi R. Kepiting Uca di hutan mangrove Indonesia. Tinjauan aspek biologi dan ekologi untuk eksplorasi. .

16. Perez DM, Heatwole SJ, Morrell LJ, Backwell PRY. Handedness in fiddler crab fights. Anim Behav. 2015;110:99–104.

17. Darnell MZ, Rittschof CC, Rittschof J, Beach C, Rittschof D. Autotomy of the major claw stimulates molting and suppresses feeding in fiddler crabs. J Exp Mar Bio Ecol. 2018;509:66–70.

18. Levinton J. Thermal stress: The role of body size and the giant major claw in survival and heat transfer of a fiddler crab (Leptuca pugilator). J Exp Mar Bio Ecol. 2020;530–531:151428.

19. Crane J. Fiddler crabs of the world: Ocypodidae: genus Uca. Princeton University Press.

20. Shih H-T, Chan BKK, Ng PKL. Tubuca alcocki, a new pseudocryptic species of fiddler crab from the Indian Ocean, sister to the southeastern African T. urvillei (H. Milne Edwards, 1852)(Crustacea, Decapoda, Brachyura, Ocypodidae). Zookeys. 2018;(747):41.

21. Akash M, Chowdhury GW. First record of the Bengal fiddler crab Uca (Austruca) bengali Crane, 1975 (Braychura: Ocypodidae) from Kuakata National Park, Bangladesh. Dhaka Univ J Biol Sci. 2017;26(2):199–203.

22. Shih H-T, Ng PKL, Davie PJF, Schubart CD, Türkay M, Naderloo R, Jones D, Liu M-Y. Systematics of the family Ocypodidae Rafinesque, 1815 (Crustacea: Brachyura), based on phylogenetic relationships, with a reorganization of subfamily rankings and a review of the taxonomic status of Uca Leach, 1814, sensu lato and its subgenera. Raffles Bull Zool. 2016;64.

23. Apreshgi KP, Dhaneesh K V, Radhakrishnan T, Kumar A. DNA barcoding of fiddler crabs Uca annulipes and U. perplexa (Arthropoda, Ocypodidae) from the southwest coast of India. J Mar Biol Assoc India. 2016;58(1):101–104.

24. Karagozlu MZ, Kim J-I, Choi T-J, Dinh T Do, Kim C-B. The complete mitochondrial genome of

Hemigrapsus penicillatus (De Haan, 1835) (Decapoda, Varunidae). Mitochondrial DNA Part B. 2018;3(1):261–262.

25. Tang B-P, Liu Y, Xin Z-Z, Zhang D-Z, Wang Z-F, Zhu X-Y, Wang Y, Zhang H-B, Zhou C-L, Chai X-Y, Liu Q-N. Characterisation of the complete mitochondrial genome of Helice wuana (Grapsoidea: Varunidae) and comparison with other Brachyuran crabs. Genomics. 2018;110(4):221–230.

26. Feng J, Huang Q, Chen H, Guo J, Lin G. Restoration of native mangrove wetlands can reverse diet shifts of benthic macrofauna caused by invasive cordgrass. J Appl Ecol. 2018;55(2):905–916.

27. Liao Y, Shou L, Tang Y, Gao A, Chen Q, Yan X, Chen J. Influence of two non-indigenous plants on intertidal macrobenthic communities in Ximen Island Special Marine Protected Area, China. Ecol Eng. 2018;112:96–104.

28. McLay C, Kitaura J, Fukui Y, Wada K. Molecular phylogenetic position of the New Zealand sentinel crab, Macrophthalmus (Hemiplax) hirtipes (Jacquinot, in Hombron & Jacquinot, 1846)(Decapoda, Brachyura, Macrophthalmidae). Crustaceana. 2010;83(11):1315–1326.

29. Marin IN. Estuarine crabs of the Okhotsk Sea and the Sea of Japan: rare species and new records. Ukr J Ecol. 2017;7(4).

30. Nour OSEDM, Stumpp M, Moron Lugo SC, Barboza FR, Pansch C. Population structure of the recent invader Hemigrapsus takanoi and prey size selection on Baltic Sea mussels. Aquat Invasions. 2020;15(2):297–317.

31. Perez DM, Christy JH, Backwell PRY. Choosing a mate in a high predation environment: female preference in the fiddler crab Uca terpsichores. Ecol Evol. 2016;6(20):7443–7450.

32. da Silva Vianna B, Miyai CA, Augusto A, Costa TM. Effects of temperature increase on the physiology and behavior of fiddler crabs. Physiol Behav. 2020;215:112765.

33. Begum S. Macrobenthic Assemblage in the Rupsha-Pasur River System of the Sundarbans Ecosystem (Bangladesh) for the Sustainable Management of Coastal Wetlands. In Coastal Wetlands: Alteration and Remediation. Springer; p.751–776.

34. De C. Geological and Geotechnical Significance. In Mangrove Ichnology of the Bay of Bengal Coast, Eastern India. Springer; p.233–276.

35. Caro T. The functional significance of coloration in crabs. Biol J Linn Soc. 2018;124(1):1–10.

36. Takeshita F. Color changes of fiddler crab between seasons and under stressful conditions: patterns of changes in lightness differ between carapace and claw. J Exp Mar Bio Ecol. 2019;511:113–119.

37. Zulfahmi I, Marlinda R, Nisa C, Paujiah E, Irfannur I, Rinaldi R, Purnama NR, Mandasari M. Size distribution, length-weight relationship and condition factor of three species male fiddler crab from jaboy mangrove wetland, Sabang, Indonesia. In IOP Conference Series: Materials Science and Engineering. IOP Publishing; p.42112.

38. Presilda CJ. Sexual dimorphism in the carapace of mud crab (Scylla serrate, Forsskal, 1775) in Magallanes, Agusandel Norte using Geometric Morphometric Analysis. Comput Ecol Softw. 2018;8(4):88.

39. Kitaura J, Wada K, Nishida M. Molecular Phylogeny of Grapsoid and Ocypodoid Crabs with Special Reference to the Genera Metaplax and Macrophthalmus. J Crustac Biol. 2002;22(3):682–693.

40. Zengel S, Pennings SC, Silliman B, Montague C, Weaver J, Deis DR, Krasnec MO, Rutherford N, Nixon Z. Deepwater Horizon Oil Spill Impacts on Salt Marsh Fiddler Crabs (Uca spp.). Estuaries and Coasts. 2016;39(4):1154–1163.

41. Lourenço PM, Catry T, Granadeiro JP. Diet and feeding ecology of the wintering shorebird assemblage in the Bijagós archipelago, Guinea-Bissau. J Sea Res. 2017;128:52–60.

42. De Grande FR, Colpo KD, Queiroga H, Cannicci S, Costa TM. Contrasting activity patterns at high and low tide in two Brazilian fiddler crabs (Decapoda: Brachyura: Ocypodidae). J Crustac Biol. 2018;38(4):407–412.

43. Wamepa K, Purwoko A, Kamal M. Studi Populasi Burung Wader (Charadriiformes) pada Akhir Musim Migrasi di Semenanjung Sembilang Banyuasin, Sumatera Selatan. J Penelit Sains. 2019;20(3):77–80.

44. Bramwell G, Schultz AG, Sherman CDH, Giraudeau M, Thomas F, Ujvari B, Dujon AM. A review of the

potential effects of climate change on disseminated neoplasia with an emphasis on efficient detection in marine bivalve populations. Sci Total Environ. 2021;775:145134.

45. Subramanian R, Retnamma J, Nagarathinam A, Loganathan J, Singaram P, Chandrababu V. Seasonality of macrobenthic assemblages and the biotic environmental quality of the largest monsoonal estuary along the west coast of India. Environ Sci Pollut Res. 2021;28(28):37262–37278.

46. Jamani S, Gholizadeh M, Patimar R, Fathabadi A. Identification and Abundance of Macrobenthic in Estuary of the Gharehsou River. J Fish. 2021;74(1):31–43.

47. Zvonareva SS, Kantor YI, Nguyen TTH, Britayev TA. Diversity and Long-Term Dynamics of the Macrobenthos in a Mangrove Plantation and Two Natural Associations of Khanh Hoa Province, Vietnam. Biol Bull. 2020;47(9):1115–1125.

48. Ramses, Ismarti, Amelia F, Rozirwan, Suheryanto. Diversity and abundance of polychaetes in the west coast waters of Batam Island, Kepulauan Riau Province-Indonesia. AACL Bioflux. 2020;13(1):381–391.

49. Rozirwan, Melki, Apri R, Fauziyah, Agussalim A, Hartoni, Iskandar I. Assessment the macrobenthic diversity and community structure in the Musi Estuary, South Sumatra, Indonesia. Acta Ecol Sin. 2021;41(4):346–350.

50. Susilo VE, Dewi MIP, Mujiono N, Subchan W, Prihatin J. The diversity of Gastropoda in grati lake district pasuruan east java. In Journal of Physics: Conference Series. IOP Publishing; p.12008.

51. Kantharajan G, Pandey PK, Krishnan P, Samuel VD, Bharti VS, Purvaja R. Molluscan diversity in the mangrove ecosystem of Mumbai, west coast of India. Reg Stud Mar Sci. 2017;14:102–111.

52. Abdollahi R, Darzi SE, Rahimian H, Naderloo R. Biodiversity of intertidal and shallow subtidal habitats in Abu Musa Island, Persian Gulf, Iran, with an updated species checklist. Reg Stud Mar Sci. 2020;33:100975.

53. Amorim RM, Delgado J de F, Neto JAB, Crapez M, Fernandez CS, e Negrello Filho OA, Fonseca EM. The benthic macrofauna along the estuarine gradient of the Paranaguá estuary. Reg Stud Mar Sci. 2020;39:101459.

54. Guan Q, Liu J, Batzer DP, Lu X, Wu H. Snails (Mollusca: Gastropoda) as potential surrogates of overall aquatic invertebrate assemblage in wetlands of Northeastern China. Ecol Indic. 2018;90:193–200.

55. Hossain MB. Trophic functioning of macrobenthic fauna in a tropical acidified Bornean estuary (Southeast Asia). Int J Sediment Res. 2019;34(1):48–57.

56. Jayachandran PR, Nandan SB, Jima M, Joseph P, Xavier NDD, Sreedevi OK, Prabhakaran MP, Joseph KJ. Macrobenthic functional feeding groups in a microtidal monsoonal estuary (Kodungallur–Azhikode estuary, India). Reg Stud Mar Sci. 2019;25:100444.

57. Joshua TJ, Toefy R, Sparks C, Kirkman SP, Samaai T. Macro-benthic invertebrate assemblages in the Betty’s Bay marine protected area (Kogelberg region South Africa). Reg Stud Mar Sci. 2018;22:1–8.

58. Park JM, Huh S-H. Epibenthic invertebrate fauna in the southern coast of the East Sea, Korea. J Asia-Pacific Biodivers. 2018;11(2):217–222.

59. Rehitha T V, Ullas N, Vineetha G, Benny PY, Madhu N V, Revichandran C. Impact of maintenance dredging on macrobenthic community structure of a tropical estuary. Ocean Coast Manag. 2017;144:71–82.

60. Suratissa DM, Rathnayake U. Effect of pollution on diversity of marine gastropods and its role in trophic structure at Nasese Shore, Suva, Fiji Islands. J Asia-Pacific Biodivers. 2017;10(2):192–198.

61. Yan J, Xu Y, Sui J, Li X, Wang H, Zhang B. Long-term variation of the macrobenthic community and its relationship with environmental factors in the Yangtze River estuary and its adjacent area. Mar Pollut Bull. 2017;123(1–2):339–348.

62. Youssef M, Madkour H, Mansour A, Alharbi W, El-Taher A. Invertebrate shells (mollusca, foraminifera) as pollution indicators, Red Sea Coast, Egypt. J African Earth Sci. 2017;133:74–85.

63. Giraldes BW, Al-Thani JAKH, Dib S, Engmann A, Alsaadi HA, Vethamony P, Alatalo JM, Yigiterhan O. Target gastropods for standardizing the monitoring of tar mat contamination in the Arabian Gulf. Reg Stud Mar Sci. 2022;53:102328.

64. Steinhausen SL, Agyeman N, Turrero P, Ardura A, Garcia-Vazquez E. Heavy metals in fish nearby

electronic waste may threaten consumer's health. Examples from Accra, Ghana. Mar Pollut Bull. 2022;175:113162.

65. Gong Y, Chai M, Ding H, Shi C, Wang Y, Li R. Bioaccumulation and human health risk of shellfish contamination to heavy metals and As in most rapid urbanized Shenzhen, China. Environ Sci Pollut Res. 2020;27(2):2096–2106.

66. EL-Shenawy NS, Loutfy N, Soliman MFM, Tadros MM, Abd El-Azeez AA. Metals bioaccumulation in two edible bivalves and health risk assessment. Environ Monit Assess. 2016;188(3):139.

67. El Nemr A, El-Said G, Ragab S, Khaled A, El-Sikaily A. The distribution, contamination and risk assessment of heavy metals in sediment and shellfish from the Red Sea coast, Egypt. Chemosphere. 2016;165:369–380.

68. Gawad SSA. Concentrations of heavy metals in water, sediment and mollusk gastropod, Lanistes carinatus from Lake Manzala, Egypt. Egypt J Aquat Res. 2018;44(2):77–82.

69. Kesavan K, Arumugam M, Vellathi V, Kumar BS. Heavy metal accumulation in molluscs and sediment from uppanar estuary, southeast coast of India. Thalassas. 2013;29:15–21.

70. Belal AAM. Macro-benthic invertebrates as a bio-indicator for water and sediment quality in Suez Bay, Red Sea. Egypt J Aquat Res. 2019;45(2):123–130.

71. Yunita F, Leiwakabessy F, Rumahlatu D. Macrozoobenthos community structure in the coastal waters of Marsegu Island, Maluku, Indonesia. Int J Appl Biol. 2018;2(1):1–11.

72. Hastuti AR, Lumbanbatu DTF, Wardiatno Y. The presence of microplastics in the digestive tract of commercial fishes off Pantai Indah Kapuk coast, Jakarta, Indonesia. Biodiversitas J Biol Divers. 2019;20(5).

73. Bayo J, Rojo D, Martínez-Baños P, López-Castellanos J, Olmos S. Commercial gilthead seabream (Sparus aurata L.) from the Mar Menor Coastal Lagoon as hotspots of microplastic accumulation in the digestive system. Int J Environ Res Public Health. 2021;18(13):6844.

74. Bakshi M, Ghosh S, Chakraborty D, Hazra S, Chaudhuri P. Assessment of potentially toxic metal (PTM) pollution in mangrove habitats using biochemical markers: A case study on Avicennia officinalis L. in and around Sundarban, India. Mar Pollut Bull. 2018;133:157–172.

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AN ECOLOGICAL ASSESSMENT OF CRAB'S DIVERSITY AMONG HABITATS OF MIGRATORY BIRDS AT BERBAK-SEMBILANG NATIONAL PARK INDONESIA

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Abstract

Crabs have an important role in the food chain among the habitat of migratory birds at Berbak-Sembilang National Park (BSNP), due to it is the main food for these birds' population. The purpose of this study was to record the crabs' species found among the habitat of migratory birds at BSNP. The methodology used is a survey by measuring environmental parameter data and sampling crabs, where the identification of species is carried out morphologically and analyzed with references. The results showed that there were three species of crabs found on the BSNP coast, where it was identified as a species of Uca dussumieri (Edwards, 1852) (C1), Metaplax longipes (Stimpson, 1858) (C2), and Metaplax distinct (Edwards, 1852) (C3). Habitat of crabs are found on fine muddy substrates at a depth of about 60 to 80 cm, pH 6.08 to 6.2, salinity 27 to 29 psu, temperature 29 to 30 °C, nitrates and phosphates in water 6.69 mg L^{-1} and 0.197 mg L^{-1}. This condition is very suitable for the growth of crabs. In the future, research should be carried out on chemical-ecological interactions of crabs and another biota.

***Keywords**: Benthic; Crustacean; Migratory birds; Mud crab; Berbak-Sembilang National Park*

Introduction

Crabs are a group of crustaceans that are easily found in the Berbak-Sembilang National Park area, which is the main food source for migratory birds while in transit twice a year. The birds are reported to have originated from Siberia in the Northern Hemisphere and Australia in the Southern Hemisphere. The birds are reported to be transiting October-November from Siberia in the northern hemisphere to Australia in the southern hemisphere, and they will transit in March-April to return to the north [1]. In the transit season, the number of birds that have been reported reaches 1600 individuals for resting and foraging for food in marine life. Crabs are their main food in the intertidal area of this habitat [2-4].

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Morphologically, the crab has a very hard carapace to protect its body, it also has a pair of claws as a means of capturing prey and defense from predators. In addition, he can run quickly into the mud using four pairs of legs. It has a color and pattern adapted to the clarity of the waters or the substrate of its habitat, such as it is bright or lighter in sandy or rocky areas. Instead, it will be dark in turbid or muddy waters [5-9]. In general, the intertidal area of the Berbak-Sembilang National Park is mud-substrate, especially in the habitat of migratory birds. Therefore, these crabs are classified as mud crabs and are very suitable for their growth [10].

Based on this information, the ecological role of crabs in the food chain in the Berbak-Sembilang National Park area is very important. Therefore, this study is indispensable for a report on the crab species that feed on migratory birds, which will greatly assist further research in the area.

Experimental part

Sampling site

Habitat crabs is a transit area for migratory birds in the Berbak-Sembilang National Park, Indonesia, which is an estuary area with extensive mangrove vegetation. The migratory birds species in this area are *Calidris alpina*, *Charadrius mongolus*, *Limosa lapponica*, *Limosa limosa*, *Limonodromus semipalmatus*, *Numenius arquata*, *Tringanebularia*, and *Tringa tetanus* [11]. Besides that, stork and shorebirds were also found [12]. However, at the sampling time of 25 October 2020, there was no large flock of migratory birds due to it was not the bird's arrival season, namely November and March. This region and its surroundings have a mud substrate, is commonly covered by mangrove *Avicennia marina* species [13-15], and is directly affected by the freshwater masses from the Barong and Banyuasin rivers [16, 17]. Map of sampling location is presented on (Fig. 1).

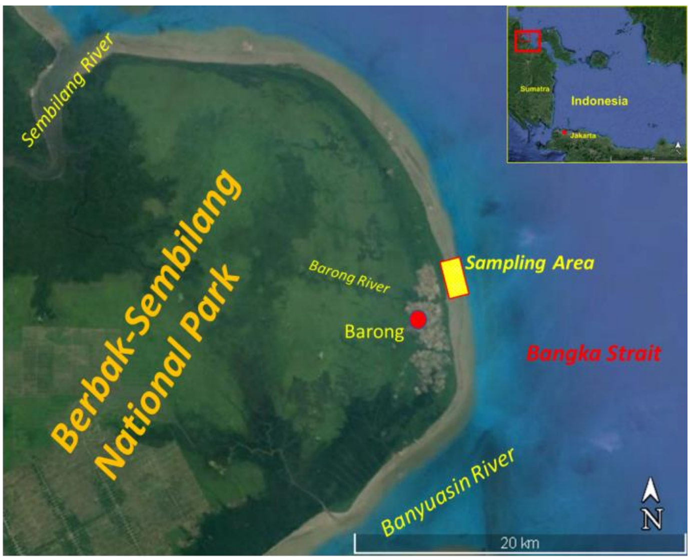

Fig. 1. Sampling site

Methods

This research was conducted using a survey method, with the location of the coordinate points 2.1638972 S and 104.9075056 ˚E. Crabs were randomly sampled by being captured in mud, washed with clean water in the plastic sample, and added with 10% formalin solution.

Environmental parameters such as salinity, temperature, pH, current, dissolved oxygen, nitrate, and phosphate are measured as supporting data.

In the laboratory, the samples were rinsed with clean water. The carapace, abdomen, legs, joints and claws were measured and weighed. Morphological identification was carried out by refer to [18-23].

Results and discussion

There were three species of crab found in the sampling location which were identified as *Uca dussumieri* (Edwards, 1852) (C1), *Metaplax longipes* (Stimpson, 1858) (C2), and *Metaplax distinct* (Edwards, 1852) (C3). The mass supply of freshwater from the Barong and Banyuasin Rivers causes the color of the water to become cloudy because it is influenced by high suspended materials (Fig. 2).

On the substrate, fine black mud was found with a depth of 60 to 100 cm. The results of the environmental parameter measured salinity was 27 to 29 psu, temperature was 29 to 30°C, pH was 6.08 to 6.2, nitrate and phosphate were 6.69 and 0.197 mg L^{-1}.

Fig. 2. Crabs habitat of migratory birds ground at Berbak-Sembilang National Park

Species of Uca dussumieri (Edwards, 1852) (C1)

There were 14 individuals coded C1-14 of the station observation. Morphologically, it looked unique in the size of the claws, which was bigger in one (Fig. 3).

Fig. 3. Details of the morphological characters *Uca dussumieri* (Edwards, 1852) species (C1) that are considered for morphometric analysis: (a) carapace, (b) cheliped, (c) leg, (d) abdomen

When the big claw is damaged or broken, it will grow back or the other claws will enlarge. It is colored bright yellowish, and rash or serrated on the surface of the dactylus, propodus and carpus. The carapace resembles a trapezoid with a wider anterior side and a pointed tip, it is called the trapezoidal carapace. It colored brownish black, dark brown and blackish orange [24]. The eyeball is black and round with a long eye shaft approaching the anterior end of the carapace. This crab has five pairs of legs, one pair in the front of the claw, and four pairs of walking legs. The abdomen is bluish in the shape of an elongated triangle.

Based on the morphological characteristics, this species is classified as a fiddler crab, it has similarities with several other species such as *Uca demani* and *Uca urvillei* [25, 26]. It can be found in muddy areas of mangrove areas [27, 28]. The results of the morphometric measurements of this species are detailed in Table 1.

Table 1. Morphometric data of *Uca dussumieri* (Edwards, 1852) species (C1)

Data	Number Code (C1)	Sample Size (mm) Min - Max	Average
Carapace Data			
Anterior carapace width (ACW)	1	12.8 – 25	18.15
Posterior carapace width (PCW)	2	5.5 – 14.27	9.92
Internal carapace width (ICW)	3	9.85 – 25	13.86
Carapace length (CL)	4	6.66 – 11.83	9.08
Eye stalk length (ESL)	5	4.72 – 9.59	6.98
Cheliped Data			
Dactyl major length (DML)	6	20.38 – 54.82	34.71
Dactyl minor length (DmL)	6	11.25 – 21.11	16.71
Propodus major width (PMW)	7	6.01 – 12.1	8.9
Propodus minor width (PmW)	7	1.72 – 2.81	2.1
Walking Leg Data			
1st Leg length (1LL)	8	14.13 – 28.23	20.98
2nd Leg length (2LL)	8	12.69 – 31	22.3
3rd Leg length (3LL)	8	12.72 – 28.08	21.05
4th Leg length (4LL)	8	11.15 – 24.45	17.73
Abdomen Data			
Abdomen length (AL)	9	5.21 – 12.83	8.43
Abdomen width (AW)	10	5.6 – 11	8.29

Spesies Metaplax longipes (Stimpson, 1858) (C2)

Only one individual was obtained at the sampling site, it had a dark brown carapace, but lighter carapace color elsewhere was also found (Fig. 4). The carapace is a rounded square with a shorter underside or is called a squarish or subquadrate carapace. This species has a pair of claws that are the same size and longer than four pairs of walking legs. The claws are orange-brown, while other features are the very long propodus part, short dactyl, and the cheliped surface is quite smooth [26]. The eyeball is black with the length of the eye shaft extending to the anterior end of the carapace.This crab has five pairs of legs consisting of one pair of claws and four walking legs. The second and third walking feet are longer than the first and fourth legs. The abdomen is light brown, and has an elongated triangular shape. The genus of this species is Metaplax from the family Varunidae. Based on the morphology and phylogenetic tree, this species has similarities with *Metaplax takahashii*, *Cyclograpsus granulosus*, *Helice wuana*, and *Eriocheir japonica* [26, 29]. Almost all species of this genus are found in muddy habitats near mangrove ecosystems, they are also found in sandy substrate dominated by seawater [29-31]. The results of the morphometric measurements of this species are detailed in Table 2.

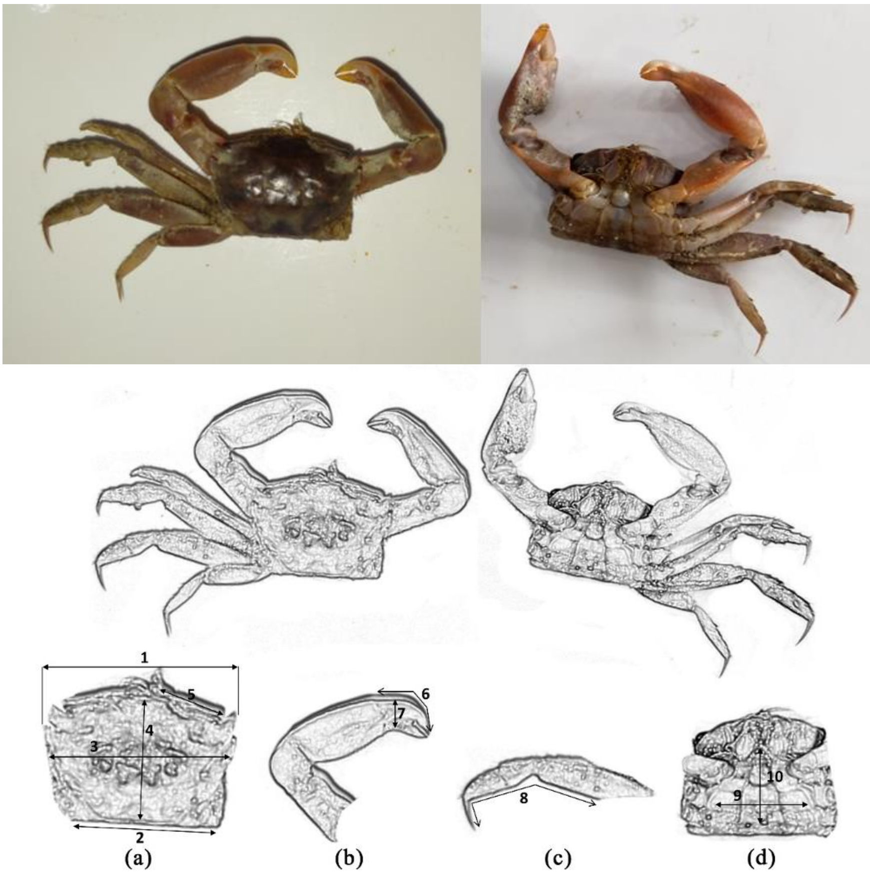

Fig. 4. Details of the morphological characters *Metaplax longipes* (Stimpson, 1858) (C2) species that considered for morphometric analysis:
(a) carapace, (b) cheliped, (c) leg, (d) abdomen

Table 2. Morphometric data of *Metaplax longipes* (Stimpson, 1858) (C2) species

Data	Number Code (C2)	Sample Size (mm)	Average
Carapace Data			
Anterior carapace width (ACW)	1	11	11
Posterior carapace width (PCW)	2	6	6
Internal carapace width (ICW)	3	8.92	8.92
Carapace length (CL)	4	6.16	6.16
Eye stalk length (ESL)	5	3.35	3.35
Cheliped Data			
Dactyl length (DL)	6	22.3	22.3
Propodus width (PW)	7	5.7	5.7
Leg Data			
1^{st} Leg length (1LL)	8	15.2	15.2
2^{nd} Leg length (2LL)	8	19.87	19.87
3^{rd} Leg length (3LL)	8	19.99	19.99
4^{th} Leg length (4LL)	8	12.76	12.76
Abdomen Data			
Abdomen length (AL)	9	7.22	7.22
Abdomen width (AW)	10	2.57	2.57

Species of Metaplax distinct (Edwards, 1852) (C3)

Two individuals were captured in the sampling location (Fig. 5). The carapace is rectangular with slightly rounded sides and a lower side that is shorter than the top which is called a subquadrate or squarish. The carapace is predominantly dark brown color, with both anterior sides tapering. The claws of this species are short and small compared to the walking legs, this indicates the sex of the female, because this female species has a pair of claws that are shorter and smaller than the male species [32, 33]. The claws are predominantly blackish red with orange dactyls. The two eyeballs are round black with a stem that extends almost to the outer side of the anterior. There are five pairs of legs, one pair of claws and four pairs of walking legs. The sizes of the second and third walking legs are longer than the first and fourth walking legs. This species is female, with a broad and rounded triangular abdomen [34]. This species has similarities with *Metaplax gocongensis* and *Metaplax indica* [7]. It is classified in the Varunidae family, also called crabs with muddy estuarine habitats, found mostly in mangrove areas and sandy beaches [31, 35]. The results of the morphometric measurements of this species are detailed in Table 3.

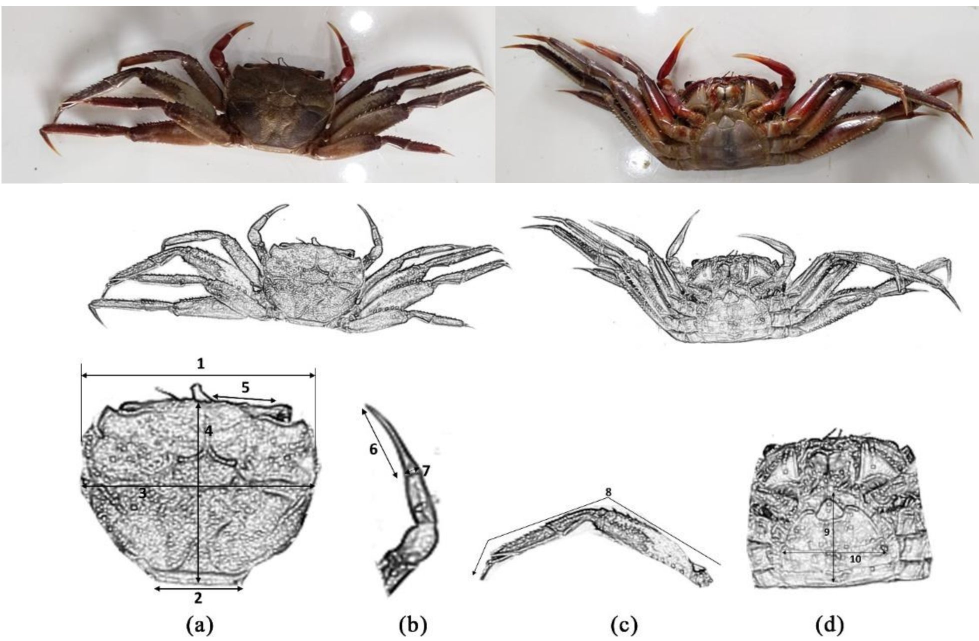

Fig. 5. Details of the morphological characters *Metaplax distinct* (Edwards, 1852) (C3) species that considered for morphometric analysis: (a) carapace, (b) cheliped, (c) leg, (d) abdomen

Table 3. Morphometric data of *Metaplax distincta* (Edwards, 1852) (C3) species

Data	**Number Code (C3)**	**Sample Size (mm) Min-Max**	**Average**
Carapace Data			
Anterior carapace width (ACW)	1	24.05 - 24.98	24.52
Posterior carapace width (PCW)	2	11.62 – 11.79	11.71
Internal carapace width (ICW)	3	22.41 – 22.42	22.42
Carapace length (CL)	4	11.04 – 12.29	11.67
Eye stalk length (ESL)	5	5.87 – 6.24	6.06
Cheliped Data			

Data	Number Code (C3)	Sample Size (mm) Min-Max	Average
Dactyl length (DL)	6	28.33 – 28.85	28.59
Propodus width (PW)	7	3.37 – 3.46	3.42
Leg Data			
1st Leg length (1LL)	8	37.76 - 38.85	38.31
2nd Leg length (2LL)	8	49.93 – 50.09	50.01
3rd Leg length (3LL)	8	54.96 – 55.18	55.07
4th Leg length (4LL)	8	41.59 - 45.55	43.57
Abdomen Data			
Abdomen length (AL)	9	17.29 – 17.41	17.35
Abdomen width (AW)	10	15.71 – 16.34	16.03

Discussion

The identification of crab species is determined based on its morphological shape. Several parts of the crab body are used as references in identification, such as the shape and pattern of the carapace, the shape and color of the claws, the shape of the eyes, the shape and number of legs, and the pattern of the abdomen [18, 36]. The carapaces of the three crab species found at the sampling location show the trapezoidal and squarish shapes, these correspond to the 14 carapace forms described by [23], the crab carapace shape is divided into 14 parts, namely longitudinally rectangular, transversely rectangular, squarish, trapezoidal, pentagonal, hexagonal, transversely hexagonal, transversely ovate, longitudinally ovate, transversely subovate, triangular, circular, subcircular, and pyriform.

Uca dussumieri (Edwards, 1852) (C1) species is unique in a pair of claws of different sizes, one larger than the other, but the shape and pattern of the claws are shown to be the same. Several studies have reported the uniqueness of the crab *Uca dussumieri* (Edwards, 1852) species. The uniqueness of the claws in this species, if there is damage or breakage, it will grow back to its original state. The process of growing a claw can be done in two ways, namely: first, it grows in the part where it is broken, and second, it grows on the part of the smallest claw that becomes enlarged [37-40]. *Uca dussumieri* (Edwards, 1852) is a fiddler crab from the Ocypodidae family [41, 42].

Uca dussumieri (Edwards, 1852) (C1) species is strongly suspected to be the *Uca dussumieri* (Edwards, 1852) species. Based on the shape and color of the carapace, this species is shown to be trapezoidal and blackish brown, while the claws are yellowish white [21]. The *Uca dussumieri* (Edwards, 1852) species is included in the crab that lives in the mud. This is also reported by [25]. Habitat of *Uca dussumieri* (Edwards, 1852) (C1) was collected around the muddy substrate mangrove area of Berbak-Sembilang National Park. This has a similarity to the *Uca dussumieri* (Edwards, 1852) habitat found by [43].

The *Metaplax longipes* (Stimpson, 1858) (C2) species have a squarish or subquadrate carapace form [26]. The carapace is dark brown with two sharp serrations on the anterior end. It has a pair of pincers the same size, cheliped this species is very long, especially the propodus, but the dactyl is relatively short and orange brown. Morphologically, this species is quite confusing to identify, but it is suspected as a species of *Metaplax longipes* (Stimpson, 1858). This species belongs to the family Varunidae is also known as the Thoracotrematan crabs family [44, 45]. The morphology of *Metaplax longipes* (Stimpson, 1858) is very similar to that of the Sesarmidae from the Grapsidae family, but the phylogenetic results are grouped into Varunidae [26, 29, 30], and it belongs to the deposit feeder crab class [46, 47].

Morphologically, *Metaplax distinct* (Edwards, 1852) (C3) has a subquadrate carapace shape, like a box and the posterior carapace tends to be rounded, is dark brown-black in color and the claws colori s reddish-black with an orange chela. This carapace is the same as the species of the Varunidae group, but differs in the shape of the smaller claws, this indicates that it is a female type, where the species of the Varunidae group have a very small pair of claws compared to the male species. In addition, the abdomen is triangular shape [37, 48]. This species can live in habitats on muddy to sandy beaches [35]. It is also found in mangrove or estuary areas [4, 49]. In some cases, this species is found with a lighter carapace color, this is due to the environment in which it lives [50, 51]. Darker carapaces are found in muddy areas, while lighter carapaces are found in substrate areas that tend to be sandy [52].

Overall, the crabs found in this study are thought to belong to the small crabs from the Ocypodidae and Varunidae families. The two families also have something in common, as reported [53], that some of the Metaplax in the Varunidae group have the same behavioral characteristics as the Ocypodidae. The morphology and way of life also have similarities with the Macrophtalmus genus of Ocypodidae. All species found have habitats in the muddy mangrove ecosystem. Crabs have a role as a food source for several predators such as shorebirds and fish [54, 55], while in the Berbak-Sembilang National Park area as feeding ground migratory birds.

The three types of crabs found sare an important analysis in the future. Furthermore, this crab data can be used to explore bioactive compounds and also to correlate the benefits and disadvantages of migratory birds as a typical organism that crosses the Berbak-Sembilang National Park area.

Conclusions

Three types of crabs caught around migratory bird habitats in Berbak-Sembilang National Park were identified as *Uca dussumieri* (Edwards, 1852), *Metaplax longipes* (Stimpson, 1858) and *Metaplax distinct* (Edwards, 1852). The environmental parameter conditions are very suitable for the growth of these crabs. In addition to the fine mud substrate habitat, this is the first reported in the region, and it is also found to be a major source of food by migratory birds. In the future, research should be carried out on ecological interactions and compound content in crabs and other biota.

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References

[1] M.N. Janra, A. Mursyid, I.G. Aadrean, M. Ringga, M. Ikhsan, *Shorebird surveys at the Coast of West Sumatra Province, Indonesia: 2017-2018*, **Stilt**, **72**, 2018, pp. 27–32.

[2] A. Purwoko, W.J. Wolff, *Low biomass of macrobenthic fauna at a tropical mudflat: An effect of latitude?*, **Estuarine, Coastal and Shelf Science**, **76**(4), 2008, pp. 869–875.

[3] S. Almaniar, Rozirwan, Herpandi, *Abundance and diversity of macrobenthos at Tanjung Api-Api waters*, *South Sumatra*, *Indonesia*, **AACL Bioflux**, **14**, 2021, pp. 1486–1497.

[4] Rozirwan, Melki, R. Apri, Fauziyah, A. Agussalim, Hartoni, I. Iskandar, *Assessment the*

macrobenthic diversity and community structure in the Musi Estuary, South Sumatra, Indonesia, **Acta Ecologica Sinica**, **41**(4), 2021, pp. 346–350.

[5] Q. Li, L. Zu, Y. Cheng, N.M. Wade, J. Liu, X. Wu, *Carapace color affects carotenoid composition and nutritional quality of the Chinese mitten crab, Eriochier sinensis*, **LWT**, **126**, 2020, pp. 109286.

[6] L.L. Costa, A. Soares-Gomes, I.R. Zalmon, *Burrow occupation rates and spatial distribution within habitat of the ghost crab Ocypode quadrata (Fabricius, 1787): Implications for impact assessments*, **Regional Studies in Marine Science**,2021, pp. 101699.

[7] P. Davie, N. Xuan, *A new species of Metaplax (Crustacea: Brachyura: Varunidae: Cyclograpsinae) from Vietnam*, **Raffles Bulletin of Zoology**, **51**, 2003, pp. 379–386.

[8] H. Fazhan, K. Waiho, I. Al-Hafiz, N.A Kasan, S.D. Ishak, N. Afiqah-Aleng, S. Tola, M. Ikhwanuddin, *Composition, size distribution, length-weight relationship of sympatric mud crab species (Scylla) and the case of presumed hybrids*, **Estuarine, Coastal and Shelf Science**, **250**, 2021, pp. 107154.

[9] A. Leoville, R. Lagarde, H. Grondin, L. Faivre, E. Rasoanirina, N. Teichert, *Influence of environmental conditions on the distribution of burrows of the mud crab, Scylla serrata, in a fringing mangrove ecosystem*, **Regional Studies in Marine Science**, **43**, 2021, pp. 101684.

[10] S. Sharifian, E. Kamrani, H. Saeedi, *Global biodiversity and biogeography of mangrove crabs: Temperature, the key driver of latitudinal gradients of species richness*, **Journal of Thermal Biology**, **92**, 2020, pp. 102692.

[11] M. Iqbal, D. Mulyana, H. Martini, A. Setiawan, I. Yustian, H. Zulkifli, *Updating recent checklist of shorebirds in Banyuasin Delta (Sembilang), South Sumatra, Indonesia*, **Stilt The Journal for the East Asian-Australasian Flyway**, **73**, 2020, pp. 69–71.

[12] W.J.M. Verheugt, H. Skov, F. Danielsen, *Notes on the birds of the tidal lowlands and floodplains of South Sumatra province, Indonesia*, **Kukila**, **6**(2), 1992, pp. 53–84.

[13] Rozirwan, H.I. Muda, T.Z. Ulqodry, *Antibacterial potential of Actinomycetes isolated from mangrove sediment in Tanjung Api-Api, South Sumatra, Indonesia*, **Biodiversitas Journal of Biological Diversity**, **21**(12), 2020.

[14] Rozirwan, Melki, R. Apri, R.Y. Nugroho, Fauziyah, A. Agussalim, I. Iskandar, *Assessment of phytoplankton community structure in Musi Estuary, South Sumatra, Indonesia*, **AACL Bioflux**, **14**, 2021, pp. 1451–1463.

[15] Rozirwan, R.Y. Nugroho, M. Hendri, Fauziyah, W.A.E. Putri, A. Agussalim, *Phytochemical profile and toxicity of extracts from the leaf of Avicennia marina (Forssk.) Vierh. collected in mangrove areas affected by port activities*, **South African Journal of Botany**, **150**, 2022, pp. 903–919.

[16] Rozirwan, Fauziyah, P.I. Wulandari, R.Y. Nugroho, F. Agustriani, A. Agussalim, F. Supriyadi, I. Iskandar, *Assessment distribution of the phytoplankton community structure at the fishing ground, Banyuasin estuary, Indonesia*, **Acta Ecologica Sinica**, 2022.

[17] A. Saputra, R.Y. Nugroho, R. Isnaini, Rozirwan, *A review: The potential of microalgae as a marine food alternative in Banyuasin Estuary, South Sumatra, Indonesia*, **Egyptian Journal of Aquatic Biology and Fisheries**, **59**, 2021, pp. 1053–1065.

[18] A. Ungfors, *Sexual maturity of the edible crab (Cancer pagurus) in the Skagerrak and the Kattegat, based on reproductive and morphometric characters*, **ICES Journal of Marine Science**, **64**(2), 2007, pp. 318–327.

[19] C. Shelley, A. Lovatelli, **Mud crab aquaculture A practical manual**, FAO Fisheries and Aquaculture Technical Paper, Rome, 2011.

[20] Z. Zhang, W. Zhang, C. Mu, R. Li, W. Song, Y. Ye, C. Shi, L. Liu, H. Wang, C. Wang, *Identification and characterization of a novel galectin from the mud crab Scylla paramamosain*, **Fish & Shellfish Immunology**, **98**, 2020, pp. 699–709.

[21] J. Crane, **Fiddler crabs of the world: Ocypodidae: genus Uca**, Princeton University Press, New Jersey, 2015.
[22] J. Zeil, J.M. Hemmi, *The visual ecology of fiddler crabs,* **Journal of Comparative Physiology A**, **192**(1), 2006, pp. 1–25.
[23] R. Naderloo, **Atlas of crabs of the Persian Gulf**, Springer, Tehran, 2017.
[24] V.Y. Mangale, B.G. Kulkarni, *Morphological Study of Fiddler Crabs in Mumbai Region*, **Advances in Bioresearch**, **4**(3), 2013.
[25] H.-T. Shih, J.-H. Lee, P.-H. Ho, H.-C. Liu, C.-H. Wang, H. Suzuki, S.-J. Teng, *Species diversity of fiddler crabs, genus Uca Leach, 1814 (Crustacea: Ocypodidae), from Taiwan and adjacent islands, with notes on the Japanese species*, **Zootaxa**, **4083**(1), 2016, pp. 57–82.
[26] H.-T. Shih, J.-W. Hsu, K.J.H. Wong, N.K. Ng, *Review of the mudflat varunid crab genus Metaplax (Crustacea, Brachyura, Varunidae) from East Asia and northern Vietnam*, **ZooKeys**, **877**, 2019, pp. 1–29.
[27] M. Shukla, B. Patel, J. Trivedi, K. Vachhrajani, *Brachyuran crabs diversity of Mahi and Dhadhar estuaries, Gujarat, India*, **Research Journal of Marine Sciences**, **2321**, 2013, pp. 1296.
[28] P. Rianta, W. Ernawati, G. Chen, S. Chen, *Diversity and abundance of mangrove fiddle crabs, genus Uca (Decapoda, Ocypodidae) at a mangrove in Kema, North Sulawesi, Indonesia*, **Acta Oceanologica Sinica**, **37**(12), 2018, pp. 92–96.
[29] Y. Liu, T.-T. Yang, Z.-Z. Xin, Q.-N. Liu, D.-Z. Zhang, B.-P. Tang, *The complete mitochondrial genome sequence of Metaplax longipes (Grapsoidea: Varunidae)*, **Mitochondrial DNA Part B**, **4**(1), 2019, pp. 1280–1282.
[30] J. Chen, Y. Xing, W. Yao, X. Xu, C. Zhang, Z. Zhang, Q. Liu, *Phylomitogenomics reconfirm the phylogenetic position of the genus Metaplax inferred from the two grapsid crabs (Decapoda: Brachyura: Grapsoidea)*, **PLOS ONE**, **14**(1), 2019, pp. e0210763.
[31] P. Chen, Y. Zhang, X. Zhu, C. Lu, *Distribution of crabs along a habitat gradient on the Yellow Sea coast after Spartina alterniflora invasion*, **PeerJ**, **7**, 2019, pp. e6775.
[32] I.N. Marin, *New data on the distribution of hairy-clawed shore crabs of the genus Hemigrapsus (Decapoda: Varunidae) along the Russian mainland coast of the Sea of Japan*, **Russian Journal of Marine Biology**, **39**(4), 2013, pp. 301–305.
[33] D. Wójcik, M. Normant, B. Dmochowska, A. Fowler, *Impact of Chinese mitten crab Eriocheir sinensis on blue mussel Mytilus edulis trossulus–laboratory studies of claw strength, handling behavior, consumption rate, and size selective predation*, **Oceanologia**, **57**(3), 2015, pp. 263–270.
[34] J. Webster, P. Clark, D. Morritt, *Laboratory based feeding behaviour of the Chinese mitten crab, Eriocheir sinensis (Crustacea: Decapoda: Brachyura: Varunidae): fish egg consumption (De Haan, 1835)*, **Aquatic Invasions**, **10**(3), 2015, pp. 313-326.
[35] B. Mohanty, A. Nayak, B. Dash, S.S. Rout, B.C. Kumar, L. Patnaik, M.K.D. Roy, A. Raman, D. Raut, *Biodiversity and ecological considerations of brachyuran crabs (Crustacea: Decapoda) from Devi estuary–mangrove region on the east coast of India*, **Regional Studies in Marine Science**, **32**, 2019, pp. 100865.
[36] C. Keenan, P. Davie, D. Mann, *A revision of the genus Scylla De Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae)*, **The Raffles bulletin of zoology**, **46**, 1998, pp. 1–29.
[37] D.M. Perez, S.J. Heatwole, L.J. Morrell, P.R.Y. Backwell, *Handedness in fiddler crab fights,* **Animal Behaviour**, **110**, 2015, pp. 99–104.
[38] M.Z. Darnell, C.C. Rittschof, J. Rittschof, C. Beach, D. Rittschof, *Autotomy of the major claw stimulates molting and suppresses feeding in fiddler crabs*, **Journal of Experimental Marine Biology and Ecology**, **509**, 2018, pp. 66–70.
[39] J. Levinton, *Thermal stress: The role of body size and the giant major claw in survival and heat transfer of a fiddler crab (Leptuca pugilator)*, **Journal of Experimental Marine**

Biology and Ecology, **530**–**531**, 2020, pp. 151428.

[40] F.W. Tina, M. Jaroensutasinee, K. Jaroensutasinee, *Effects of body size, resident status and handedness on fighting behaviour of the fiddler crab, Uca bengali Crane, 1975*, **Crustaceana**, **88**(7–8), 2015, pp. 775–789.

[41] M. Akash, G.W. Chowdhury, *First record of the Bengal fiddler crab Uca (Austruca) bengali Crane, 1975 (Braychura: Ocypodidae) from Kuakata National Park, Bangladesh*, **Dhaka University Journal of Biological Sciences**, **26**(2), 2017, pp. 199–203.

[42] H.-T. Shih, B.K.K. Chan, P.K.L. Ng, *Tubuca alcocki, a new pseudocryptic species of fiddler crab from the Indian Ocean, sister to the southeastern African T. urvillei (H. Milne Edwards, 1852)(Crustacea, Decapoda, Brachyura, Ocypodidae)*, **ZooKeys**,(747), 2018, pp. 41.

[43] K.P. Apreshgi, K. V Dhaneesh, T. Radhakrishnan, A. Kumar, *DNA barcoding of fiddler crabs Uca annulipes and U. perplexa (Arthropoda, Ocypodidae) from the southwest coast of India*, **Journal of the Marine Biological Association of India**, **58**(1), 2016, pp. 101–104.

[44] M.Z. Karagozlu, J.-I. Kim, T.-J. Choi, T. Do Dinh, C.-B. Kim, *The complete mitochondrial genome of Hemigrapsus penicillatus (De Haan, 1835) (Decapoda, Varunidae)*, **Mitochondrial DNA Part B**, **3**(1), 2018, pp. 261–262.

[45] B.-P. Tang, Y. Liu, Z.-Z. Xin, D.-Z. Zhang, Z.-F. Wang, X.-Y. Zhu, Y. Wang, H.-B. Zhang, C.-L. Zhou, X.-Y. Chai, Q.-N. Liu, *Characterisation of the complete mitochondrial genome of Helice wuana (Grapsoidea: Varunidae) and comparison with other Brachyuran crabs*, **Genomics**, **110**(4), 2018, pp. 221–230.

[46] J. Feng, Q. Huang, H. Chen, J. Guo, G. Lin, *Restoration of native mangrove wetlands can reverse diet shifts of benthic macrofauna caused by invasive cordgrass*, **Journal of Applied Ecology**, **55**(2), 2018, pp. 905–916.

[47] Y. Liao, L. Shou, Y. Tang, A. Gao, Q. Chen, X. Yan, J. Chen, *Influence of two non-indigenous plants on intertidal macrobenthic communities in Ximen Island Special Marine Protected Area, China*, **Ecological Engineering**, **112**, 2018, pp. 96–104.

[48] B. da Silva Vianna, C.A. Miyai, A. Augusto, T.M. Costa, *Effects of temperature increase on the physiology and behavior of fiddler crabs*, **Physiology & behavior**, **215**, 2020, pp. 112765.

[49] S. Begum, **Macrobenthic Assemblage in the Rupsha-Pasur River System of the Sundarbans Ecosystem (Bangladesh) for the Sustainable Management of Coastal Wetlands, In Coastal Wetlands: Alteration and Remediation**. Springer, Cham, 2017.

[50] T. Caro, *The functional significance of coloration in crabs*, **Biological Journal of the Linnean Society**, **124**(1), 2018, pp. 1–10.

[51] F. Takeshita, *Color changes of fiddler crab between seasons and under stressful conditions: patterns of changes in lightness differ between carapace and claw*, **Journal of Experimental Marine Biology and Ecology**, **511**, 2019, pp. 113–119.

[52] I. Zulfahmi, R. Marlinda, C. Nisa, E. Paujiah, I. Irfannur, R. Rinaldi, N.R. Purnama, M. Mandasari, *Size distribution, length-weight relationship and condition factor of three species male fiddler crab from jaboy mangrove wetland, Sabang, Indonesia*, **IOP Conference Series: Materials Science and Engineering - The 5th Annual Applied Science and Engineering Conference**, 20-21 April 2020, Bandung Barat, Indonesia, p. 42112.

[53] J. Kitaura, K. Wada, M. Nishida, *Molecular Phylogeny of Grapsoid and Ocypodoid Crabs with Special Reference to the Genera Metaplax and Macrophthalmus*, **Journal of Crustacean Biology**, **22**(3), 2002, pp. 682–693.

[54] S. Zengel, S.C. Pennings, B. Silliman, C. Montague, J. Weaver, D.R. Deis, M.O. Krasnec, N. Rutherford, Z. Nixon, *Deepwater Horizon Oil Spill Impacts on Salt Marsh Fiddler Crabs (Uca spp.)*, **Estuaries and Coasts**, **39**(4), 2016, pp. 1154–1163.

[55] G. Dumitru, E. Todirascu-Ciornea, L. Hritcu, I.G. Sandu, *Studies of some morphological and biochemical parameters concerning the health condition of some fish species from Prut River, Romania*, **Revista de Chimie**, **69**(5), 2018.

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Mollusks diversity in the protected coastline of Berbak-Sembilang National Park Indonesia

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Abstract:	Mollusks are filter feeder biota that has a role as a food source in aquatic ecosystems. Presumably, there has been a decrease in its diversity on the protected coastline of Berbak-Sembilang National Park (BSNP), due to fluctuations of changes in water quality parameters that threaten the sustainability of another biota in the web food system. The purpose of this study was to describe the diversity of mollusks and their correlation with water quality parameters in the protected coastline area of BSNP. The research methodology was carried out, namely: water quality data collection (salinity, dissolved oxygen, pH, temperature, brightness, current, nitrate, and phosphate), mollusk sampling, diversity analysis was used by Shannon-Wiener and Simpson index, and correlation analysis was used by principal component analysis (PCA) and similarity analysis. The results showed that there were 28 species of mollusks which were classified into two classes: Bivalve 79% with 7 species, and Gastropod 49% with 21 species. Water quality parameters were found in normal conditions with a mean pH value of waters 7.29±0.59, salinity 30.38±1.30 ppt, DO 7.78±0.78 mg L-1, temperature 29.49±0.14 oC, brightness 15.45±6.18%, current velocity 0.18 ± 0.12 m s-1, nitrate 6.08±0.48 mg L-1, and phosphate 0.18±0.01 mg L-1. The mollusks abundance means 263.25 ind m-2, and the diversity is categorized as low H'<1 except stations 2 and 4, it is supported by the dominant species namely: Anadara granosa 37.61% and Nutricola sp 35.47%. Based on PCA correlation and similarity analysis is shown that two clusters of mollusks diversity distribution area are formed, namely; open coastal areas are characterized by higher temperature, nutrients, salinity, pH, currents, and brightness, and estuary clusters are characterized by higher dissolved oxygen and mollusk abundance.
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Prof. Jong Seong Khim
Editor-in-Chief
Regional Studies in Marine Science
August 29, 2022

Dear Prof. Jong Seong Khim
I am pleased to submit an original research article entitled "Mollusks diversity in the protected coastline of Berbak-Sembilang National Park Indonesia" by Rozirwan, Fauziyah, Redho Yoga Nugroho, Tengku Zia Ulqodry, Wike Ayu Eka Putri, Afan Absori, and Iskhaq Iskandar for publication in the Regional Studies in Marine Science. We previously explored the community structure of macrobenthos in Musi River and Api-api Cape, South Sumatra (Almaniar et al., 2021; Rozirwan et al., 2021). The two previous studies were near by to the location of this study that was in a protected area. This manuscript was constructed to explore the community stucture of mollusks in the mud flat that was protected area of Berbak Sembilang National Park, South Sumatra. The results of this study were important to be published as a reference for further research.

In this manuscript, bivalves and gastropods had dominant presence and abundance allowed for their role as a significant food source for migratory birds in the mangrove mud flat. This study implicitly revealed the existence of mollusks in influencing ecological processes in the mangrove mud flat of Berbak Sembilang National Park, South Sumatra.

We believe that this manuscript is appropriate for publication by the Regional Studies in Marine Science because it is appropriate with the journal's aims and scope https://www.sciencedirect.com/journal/regional-studies-in-marine-science/about/aims-and-scope.

This manuscript has not been published and is not under consideration for publication elsewhere. We have no conflicts of interest to disclose, but we do respectfully request that Prof. Jong Seong Khim review our manuscript.

Thank you for your consideration

Sincerely

Dr. Rozirwan
Department of Marine Science
Sriwijaya University

Highlights

- We report two biggest classes of mollusks in the protected coastline of Berbak-Sembilang National Park.
- Bivalves are more diverse although two species are dominant in muddy intertidal areas.
- *Anadara granosa* dan *Nutricola* sp. were commonest species.
- Water quality parameters affect the biodiversity distribution of mollusks

Mollusks diversity in the protected coastline of Berbak-Sembilang National Park Indonesia

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Abstract

Mollusks are filter feeder biota that has a role as a food source in aquatic ecosystems. Presumably, there has been a decrease in its diversity on the protected coastline of Berbak-Sembilang National Park (BSNP), due to fluctuations of changes in water quality parameters that threaten the sustainability of another biota in the web food system. The purpose of this study was to describe the diversity of mollusks and their correlation with water quality parameters in the protected coastline area of BSNP. The research methodology was carried out, namely: water quality data collection (salinity, dissolved oxygen, pH, temperature, brightness, current, nitrate, and phosphate), mollusk sampling, diversity analysis was used by Shannon-Wiener and Simpson index, and correlation analysis was used by principal component analysis (PCA) and similarity analysis. The results showed that there were 28 species of mollusks which were classified into two classes: Bivalve 79% with 7 species, and Gastropod 49% with 21 species. Water quality parameters were found in normal conditions with a mean pH value of waters 7.29±0.59, salinity 30.38±1.30 ppt, DO 7.78±0.78 mg L^{-1}, temperature 29.49±0.14 ^{o}C, brightness 15.45±6.18%, current velocity 0.18 ± 0.12 m s^{-1}, nitrate 6.08±0.48 mg L^{-1}, and phosphate 0.18±0.01 mg L^{-1}. The mollusks abundance means 263.25 ind m^{-2}, and the diversity is categorized as low H'<1 except stations 2 and 4, it is supported by the dominant species namely: *Anadara granosa* 37.61% and *Nutricola* sp 35.47%. Based on PCA correlation and similarity analysis is shown that two clusters of mollusks diversity distribution area are formed, namely; open coastal areas are characterized by higher temperature, nutrients, salinity, pH, currents, and brightness, and estuary clusters are characterized by higher dissolved oxygen and mollusk abundance.

Keywords*:* Bivalve, Gastropod, Macrobenthos, Mollusks diversity, Protected coasline

1. Introduction

Mollusks are a group of aquatic benthic, which are infauna and epifauna with limited movement. Its existence is very vulnerable to be influenced by various changes in environmental quality. Aquatic subtracts such as mud, sand, and rocks are reported to have many differences in the diversity of these biotas. Diversity mollusks are very easy to find at the bottom of the water with a substrate of mud and sand (Abdelhady et al., 2019; Kabir et al., 2014; Rozirwan et al., 2021a). Although also found in rock substrates (Joesidawati, 2018; Sahidin et al., 2018), mollusks on mud substrates were found to be more diverse due to the nature of their filter feeders, especially in mangrove ecosystems (Ariyanto, 2019; Islamy and Hasan, 2020; Rozirwan et al., 2021a). On the other hand, the mollusks were a major food source for demersal fish and seabirds (Crooks, 2002). Several species of shorebirds, storks, and seabirds were found to prey on mollusks (Iqbal et al., 2020; Janra et al., 2018). Various threats will reduce the diversity of mollusks in various habitats. Most of the larval stages of macrofauna were planktonophagous, as food for large zooplankton and fish, which significantly affected the number and species composition of macrofauna (Liu et al., 2019; Rozirwan et al., 2021b).

Berbak-Sembilang National Park (BSNP) is an estuary area located on the coast of Sumatra Island with a long coastline covered by a wide mangrove forest. they are supported by a thick and nutrient-rich mud substrate which has an impact on increasing the abundance and diversity of biota, especially benthic organisms. There are 32 mangrove species in BSNP with an area of 70,263 hectares (Ratmoko et al., 2021). Nevertheless, this area has decreased from year to year due to many factors such as forest fires, coastal abrasion, forest encroachment by residents, and the creation of pond shrimp farming (Sarno et al., 2018). The destruction of mangrove forests has a very significant impact on decreasing the abundance and diversity of benthic organisms, especially the mollusk phylum, where their limited movement causes them to adapt to the fluctuation's environmental changes (Wu et al., 2018). Furthermore, the linkage of mollusks with mangrove ecosystems is very high, because mangroves are the main food source, and thick silt is a very suitable habitat for their growth (Feng et al., 2018).

The dynamics of changing water quality have an impact on decreasing the mollusks community structure in an area, it will be exacerbated by an increase of the anthropogenic waste (Calle et al., 2018; Suratissa and Rathnayake, 2017; Zaki et al., 2021). However, a decrease in mollusks diversity can also occur in protected areas such as the BSNP, especially in the coastal areas, which are vulnerable to environmental changes. This has a significant impact on the diversity of mollusks as a sessile biota with very limited movement (Almaniar et al., 2021; Reis et al., 2021). In addition, the discharge of water masses from land carrying suspended substances and organic matter has an impact on increasing the distribution of abundance and diversity of mollusks (Fonseca et al., 2020; Rehitha et al., 2017), this occurs naturally and continuously over time (Marsden and Baharuddin, 2015; Yan et al., 2017).

This study aims to examine the diversity of mollusks in the protected coastline of BSNP. In addition, it is also to update data on mollusks as the largest group of benthic organisms reported in the tropical coastal area of the eastern part of Sumatra Island.

2. Materials and Methods

2.1 Study area

The Berbak-Sembilang National Park (BSNP) is a mangrove forest conservation area of about 2,051 km^2 (Sarno et al., 2018; Sarno et al., 2017). This area has a thick mud subtract, sourced from some rivers around it such as the Sembilang river, Barong river, and Banyuasin river. In addition, this coastal area has endemic biota such as the Sembilang fish (*Plotusus canius*), the giant freshwater turtle (*Chitra indica*), the saltwater crocodile (*Crocodylus porosus*), and a habitat for several types of shorebirds, storks, and migratory birds (Iqbal et al., 2020). Macrobenthos in this area is the main food of these birds.

The protected coastline of the BSNP was specifically targeted for this study (**Fig. 1**). BSNP is located on the western coast of the Bangka Strait, South Sumatra, which is an estuary area formed from a mixture of freshwater masses from the mainland of Sumatra with seawater masses from the Melaka Strait and the South China Sea (Rozirwan et al., 2019). The BSNP coastline has dynamic water quality parameters, which are during the rainy season and the dry season. In the rainy season, freshwater discharge from the mainland will increase which results in a decrease in salinity, brightness, and an increase in nutrients. In addition, high mangrove waste will increase water fertility. In contrast, in the dry season, there are clearer waters, and an increase in salinity, due to the dominant influence of seawater masses. Overall, the BSNP estuary shows a dynamic environment, where water quality parameters are directly/indirectly influenced by different seasons and/or episodic events of freshwater input to the offshore (Ratmoko et al., 2021).

This research was conducted at eight observation stations in the protected coastline of BSNP waters with a length of about 60 km. Stations 1 and 2 represent the bay area and the open coast. Stations 3, 4, and 5 represent river estuary areas, while Stations 6, 7, and 8 represent open shore areas and migratory bird habitats.

Fig. 1. Map of sampling stations in Berbak-Sembilang National Park

2.2 Data collection and sampling processing

Data on the water physical parameters (i.e. pH, salinity, dissolved oxygen, temperature, brightness, and current speed) are carried out *in*-situ with three repetitions at the observation station, respectively. Measurements used for the water pH with a pH meter, salinity with a hand refractometer, dissolved oxygen (DO) with a DO meter, temperature with a digital thermometer, brightness with Secchi disk, and current speed with a current meter. Nitrate and phosphate measurements used a spectrophotometer.

Mollusks samples were collected on sediments with a depth of 20 cm and a transect area of 1 x 1 m. A sampling at the station was carried out three times, respectively. Then the samples were put into plastic samples and labeled by each station for further analysis. The mollusks sample obtained was separated from sediment, washed with clean water, and preserved with 8% formalin

(Weerman et al., 2011), and samples identified by refer to (Hibberd, 2009; Purchon, 2013; Sturm et al., 2006).

2.3 Statistical analysis

Data analysis on water quality parameters was described using MS Excel software. The mollusks abundance data were analyzed of total percentage and total individual per species. The species diversity data were analyzed by the Shannon-Winner index (H ') and the Dominance Index by Simpson (C). Principle component analysis (PCA) was used to analyze the correlation between water quality parameters and the abundance and diversity of mollusks and the similarity of stations were analyzed by Bray-Curtis dissimilarity analysis using XLSTAT 2021.

3. Results

3.1 Water quality parameters of Berbak-Sembilang National Park

The results of the measurement of the quality of waters in the coastal area of BSNP show that the conditions are relatively stable or normal for the growth of mollusks. The average pH value of the waters was obtained under normal conditions of 7.29 ± 0.59, as well as salinity of 30.38 ± 1.30 ppt, although there was a slight decrease at station 8 (28 ppt), this is normal in the estuary area.

Dissolved oxygen (DO) and temperature in all observation stations were categorized in good condition with mean values were 7.78 ± 0.78 mg L^{-1} and 29.49 ± 0.14 °C, but brightness showed a low mean value of 15.45 ±6.18%, especially in the estuary area. rivers, namely: stations 3, 4, and 5. The flow velocity was found to be decreasing in the bay or estuary area with an average value of 0.18 ± 0.12 m s^{-1}, while the distribution of nitrate and phosphate concentrations was shown to be relatively even with a mean of 6.08 ± 0.48 mg L^{-1}, and 0.18 ± 0.01 mg L^{-1} (**Table 1**).

Table 1

Water quality parameters of Berbak-Sembilang National Park

3.2 Mollusks species of community structure

The composition of mollusks in all observation stations was found to be only two classes which were dominated by Bivalve 79% and Gastropod 21%. The distribution of these two classes is uneven, where they are only found at certain stations.

Fig. 2. Mollusks community structure in Berbak-Sembilang National Park

A total of 28 species of mollusks were identified in BSNP, nominated by the Gastropod class with 21 species, while the Bivalve class with 7 species. However, the abundance of Bivalves was found more than Gastropod. The distribution of the abundance and diversity of species was found to be uneven, such as *Anadara granosa*, which was found in almost all observation stations, but more species were found in only one or two at the station.

Table 2
Mollusks species of Berbak-Sembilang National Park

3.3 Mollusks abundance and diversity

The overall mean value of individuals mollusks at the study sites was 263.25 ind m^{-2}. The highest abundance found at station 4 is 531 ind m^{-2}, station 3 is 495 ind m^{-2}, station 6 is 333 ind m^{-2}, and station 5 is 297 ind m^{-2}, while others are taken as the average found. Two species of mollusks were found to dominate, namely: *Anadara granosa* 37.61% and *Nutricola* sp. 35.47%, both of which are from the Bivalve class, in contrast to the abundance of the Gastropod class which was dominated by *Pterygia dactylus* 5.56% and *Volema pyrum* 2.14%. In addition, the distribution of the Bivalve class was found to be more even than that of Gastropod.

Fig. 3. Percentage of mollusks species of Berbak-Sembilang National Park

Given the diversity of species, the Shannon-Wiener index (H ') all decreased significantly at almost all low-category observation stations (Station 1, 3, 5, 6, 7, and 8), unless there were two stations in the moderate category (Station 2 and 4). This is also supported by the Simpson index value (C), where species dominance occurs in almost all locations (**Fig. 4**).

Fig. 4. Diversity index of mollusks of Berbak-Sembilang National Park

3.4 Correlation between water quality parameters with mollusks abundance and diversity of Berbak-Sembilang National Park

The results of the relationship between water quality parameters and mollusks abundance and diversity at the study location obtained Eigenvalues Cumulative 82.61%, five groups were formed, namely: four groups formed on the F1 and F2 axes, while the others were formed on the F3 axis. Besides that, the similarity between the observation stations was formed by two clusters coded MB1 and MB2 (**Fig. 5**).

Based on **Fig. 5a-5b**, *the first group* contributing from the positive F1 axis illustrated that stations 1 and 8 are characterized by higher temperatures, concentrations of nitrate and phosphate, which is thought to be influenced by a larger supply of land. *The second group* is formed on the negative F1 axis by showing that stations 3 and 5 are characterized by a higher abundance of mollusks, where they are located just around the mouth of the Sembilang river. *The three group*s are formed on the positive F2 axis which is illustrated that Station 6 with a stronger characteristic of current velocity and water brightness, is assumed that the location is directly facing the open sea. *The fourth group* is formed on the negative F2 axis where station 4 is characterized by higher oxygen, presumably, there is an influence of the mixing area between the water mass of the river and the sea. *The fifth group* is formed on the positive F3 axis, it is found that stations 2 and 7 are characterized by more stable salinity and pH, this is thought to reduce the influence of the freshwater mass from the river.

Fig. 5. Correlation between water quality parameters with mollusks abundance and diversity, (a) F1 and F2 axes; (b) F3 axes; (c) Dendrogram dissimilarity

The results of the similarity analysis calculated by the Bray-Curtis dissimilarity index (**Fig. 5c)** showed that the distribution of mollusks abundance and diversity was significantly similar, formed two clusters (MB1 and MB2). An average similarity value of 83.74%. MB1 clusters are formed at stations 1, 2, 6, 7, and 8 which are on the open coast. These clusters are characterized by higher temperature, salinity, pH, nutrient brightness, and water currents. This is thought to be due to the strong influence of the seawater mass area of the Melaka Strait and the South China Sea.

The MB2 cluster is formed by stations 3, 4, and 5, located at the mouth of the river mouth, characterized by dissolved oxygen and a higher abundance of mollusks compared to other locations. Continuous fluctuation in water quality parameters is thought to have an impact on the dominance of several species at each station. The two clusters illustrated that the abundance and diversity of mollusks on the protected coastline of BSNP were significantly affected by changes in water quality parameters.

Discussion

The fluctuation of water quality parameters in all observation stations of the Berbak-Sembilang National Park (BSNP) was found to be slightly different, and this is a good condition for the growth of aquatic biota, especially mollusks. There are several parameters found to decrease in the estuary area, such as brightness and speed of currents, this is due to the impact of the stirring of the water mass from the land with the seawater mass formed in the mixing area. This was also reported by (Guerra-García et al., 2021; Lv et al., 2019; Pelletier et al., 2021; Rozirwan et al., 2022; Saputra et al., 2021).

There are 28 species of mollusks found on the protected coastline of the BSNP, grouped into two classes, namely Bivalve 79% with 7 species, and Gastropod 21% with 27 species. The individual composition of the Bivalve class is more dominant than that of Gastropod, although the number of species is lower. Bivalves have a high tolerance ability to changes in environmental parameters (Bramwell et al., 2021). This composition has also been reported on the west coast of India (Subramanian et al., 2021), in the estuary of the Gharehsou River (Jamani et al., 2021), in a mangrove plantation and two natural associations of Khanh Hoa, Vietnam (Zvonareva et al., 2020). In contrast to the reported that Polychaeta is more dominant in Yangtze River Estuary and the Batam Island, Indonesia (Ramses et al., 2020), Gastropod is found to be dominant in Estuary Musi (Rozirwan et al., 2021a), Gastropod is also dominant in grate lake district Pasuruan East Jawa (Susilo et al., 2021), Gastropods dominated of Mumbai, west coast of India (Kantharajan et al., 2017). This indicates that the individual distribution of the two classes of mollusks is highly dependent on their habitat.

The abundance of mollusks was found to be quite high, which increased significantly in the estuary area compared to the open coastal area. This is thought to be influenced by the discharge of water masses from the land carrying more suspended material and nutrients. Besides that, the meeting of water masses creates a mixing area which has an impact on increasing the fertility of the waters. This condition is very suitable for the growth and reproduction of the mollusk community as aquatic sessile biota. This total abundance was higher than that reported by (Abdollahi et al., 2020; Amorim et al., 2020; Guan et al., 2018; Hossain, 2019; Jayachandran et al., 2019; Joshua et al., 2018; Park and Huh, 2018; Rehitha et al., 2017; Suratissa and Rathnayake, 2017; Yan et al., 2017; Youssef et al., 2017).

There are two species found to dominate in BSNP, namely: *Anadara granosa* 37.61% and *Nutricola* sp. 35.47%, classified in the Bivalve class (Opa et al., 2021; Saffian et al., 2020; Wells et al., 2021). Gastropod class abundance was shown by *Pterygia dactylus* 5.56% and *Volema pyrum* 2.14% species (Amarasinghe et al., 2021; Rekha et al., 2021; Susilo et al., 2021). The distribution of *A. granosa* and *Nutricola* sp. species were found to be more even than other species. This species is reported to have a stronger survival ability (Bramwell et al., 2021; Li et al., 2020; Marsden and Baharuddin, 2015). In contrast to what was reported by (Noh et al., 2019), identified bivalves of *Mactra veneriformis* and *Cyclina sinensis* were more resistant to the organic matter in the Geum River estuary.

The relationship between water quality parameters on abundance and diversity of mollusks in the protected coastline in BSNP is characterized by higher temperature and nutrients in the river mouth area, while the brightness and flow velocity are lower. The discharge of inland water masses through rivers is affected, where it brings temperature, nutrients, and suspended materials to a higher level and there is a mixing of freshwater and seawater which makes the current slowdown. The number of individual mollusks in the estuary area is higher and more diverse than others. This was also reported by (Amorim et al., 2020), that the benthic community responded to oxygen concentrations, salinity, and particle size. The BSNP open coastal areas are characterized by higher temperature, nutrient, salinity, pH, current, and brightness parameters. It is assumed that the influence of seawater masses from the Malacca Strait and the South China Sea is more dominant, it has an impact on the decline in mollusks diversity. (Xingzhong et al., 2002) pointed out that macrofauna was sensitive to the changes in the pelagic environment. (Xingzhong et al., 2002) found that along the estuary gradient, benthic species number increased with the increase of salinity. The salinity gradient was the dominant factor determining the distribution pattern of mollusks in protecting the coastline of BSNP, and currents play a role in water mass distribution and diversity of mollusks with limited movement, especially on juvenile faces (Reis et al., 2021).

There are two clusters for mollusk habitat in BSNP, namely: the open coastal cluster and the estuary water cluster. The open coastal cluster found the diversity of mollusks slightly lower than the estuary cluster dominated by the Bivalve class. It is shown that the freshwater mass of the river is more suitable for the growth and reproduction of mollusks than the open coast. Variation in macrobenthic diversity may be primarily attributed to changes in stem density and salinity (Lv et al., 2019). As estuaries are complex diverse ecosystems, benthic communities are controlled by a combination of factors, such as salinity, pH, tidal fluctuation, dissolved oxygen, sediment composition, and organic matter, and no single factor could be considered as an ecological 'master' factor (Hossain and Hossain, 2021).

Conclusions

There are 28 species of mollusks found on the protected coastline of Berbak-Sembilang National Park, classified into two classes, bivalves 79% with 7 species, and gastropods 49% with 21 species. Water quality parameters were found under normal conditions and supported for mollusk growth. The abundance was found to be uneven, both in the estuary area and on the open sea coast. The diversity of species is categorized as low, this is supported by the species that dominate, namely; *Anadara granosa* 37.61% and *Nutricola* sp. 35.47%. Based on PCA, it shows that the observation stations in open coastal areas are characterized by higher nutrients, salinity, pH, currents, and temperatures, while the estuary areas are characterized by higher dissolved oxygen and mollusk abundance. Similarity analysis has formed that the two clusters of distribution of mollusk diversity in BSNP, namely open coastal areas and river estuaries, are both significantly different influenced by water quality fluctuations.

Credit authorship contribution statement

Rozirwan: Sampling, identification, Formal analysis, Writing – original draft. **Fauziyah**: sampling, identification, writing. **Redho Yoga Nugroho**: Sampling, identification, Formal analysis, Writing – original draft. **Tengku Zia Ulqodry**: Formal analysis, reviewing. **Wike Ayu Eka Putri**: Formal analysis, writing, reviewing, and editing. **Afan Absori**: formal analysis sediment fractions. **Iskhaq Iskandar**: reviewing, and editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Reference

Abdelhady, A.A., Khalil, M.M., Ismail, E., Fan, J., Zhang, S., Xiao, J., 2019. Water chemistry and

substrate type as major determinants of molluscan feeding habit and life–mode in lagoon sediments. Estuar. Coast. Shelf Sci. 220, 120–130.
Abdollahi, R., Darzi, S.E., Rahimian, H., Naderloo, R., 2020. Biodiversity of intertidal and shallow subtidal habitats in Abu Musa Island, Persian Gulf, Iran, with an updated species checklist. Reg. Stud. Mar. Sci. 33, 100975.
Almaniar, S., Rozirwan, Herpandi, 2021. Abundance and diversity of macrobenthos at Tanjung Api-Api waters, South Sumatra, Indonesia. AACL Bioflux 14, 1486–1497.
Amarasinghe, A.A.T.N., Eswaramohan, T., Gnaneswaran, R., 2021. Gastropods Diversity in Thondaimanaru Lagoon (Class: Gastropoda), Northern Province, Sri Lanka. J. Geosci. Environ. Prot. 9, 21–30.
Amorim, R.M., Delgado, J. de F., Neto, J.A.B., Crapez, M., Fernandez, C.S., e Negrello Filho, O.A., Fonseca, E.M., 2020. The benthic macrofauna along the estuarine gradient of the Paranaguá estuary. Reg. Stud. Mar. Sci. 39, 101459.
Ariyanto, D., 2019. Food preference on Telescopium telescopium (Mollusca: Gastropoda) based on food sources in mangrove ecosystem. Plant Arch. 19, 913–916.
Bramwell, G., Schultz, A.G., Sherman, C.D.H., Giraudeau, M., Thomas, F., Ujvari, B., Dujon, A.M., 2021. A review of the potential effects of climate change on disseminated neoplasia with an emphasis on efficient detection in marine bivalve populations. Sci. Total Environ. 775, 145134.
Calle, P., Monserrate, L., Medina, F., Delgado, M.C., Tirapé, A., Montiel, M., Barzola, O.R., Cadena, O.A., Dominguez, G.A., Alava, J.J., 2018. Mercury assessment, macrobenthos diversity and environmental quality conditions in the Salado Estuary (Gulf of Guayaquil, Ecuador) impacted by anthropogenic influences. Mar. Pollut. Bull. 136, 365–373.
Crooks, J.A., 2002. Predators of the invasive mussel Musculista senhousia (Mollusca: Mytilidae). Pacific Sci. 56, 49–56.
Feng, J., Huang, Q., Chen, H., Guo, J., Lin, G., 2018. Restoration of native mangrove wetlands can reverse diet shifts of benthic macrofauna caused by invasive cordgrass. J. Appl. Ecol. 55, 905–916. https://doi.org/https://doi.org/10.1111/1365-2664.12987
Fonseca, E.M., Fernandes, J.R., Lima, L.S., Delgado, J., Correa, T.R., Costa, P.M.S., Neto, J.A.B., Aguiar, V.M.C., 2020. Effects of dredged sediment dumping on trace metals concentrations and macro benthic assemblage at the continental shelf adjacent to a tropical urbanized estuary. Ocean Coast. Manag. 196, 105299.
Guan, Q., Liu, J., Batzer, D.P., Lu, X., Wu, H., 2018. Snails (Mollusca: Gastropoda) as potential surrogates of overall aquatic invertebrate assemblage in wetlands of Northeastern China. Ecol. Indic. 90, 193–200.
Guerra-García, J.M., Navarro-Barranco, C., Ros, M., Sedano, F., Espinar, R., Fernández-Romero, A., Martínez-Laiz, G., Cuesta, J.A., Giráldez, I., Morales, E., 2021. Ecological quality assessement of marinas: An integrative approach combining biological and environmental data. J. Environ. Manage. 286, 112237.
Hibberd, T., 2009. Field identification guide to Heard Island and McDonald Islands benthic

invertebrates. Deep. Res. Part Ii-Topical Stud. Oceanogr. 53, 985–1008.

Hossain, I., Hossain, M.B., 2021. Community structure of macrobenthos in homestead ponds of Noakhali coast, Bangladesh. Acta Ecol. Sin. 41, 611–619.

Hossain, M.B., 2019. Trophic functioning of macrobenthic fauna in a tropical acidified Bornean estuary (Southeast Asia). Int. J. Sediment Res. 34, 48–57.

Iqbal, M., Mulyana, D., Martini, H., Setiawan, A., Yustian, I., Zulkifli, H., 2020. Updating recent checklist of shorebirds in Banyuasin Delta (Sembilang), South Sumatra, Indonesia. Stilt J. East Asian-Australasian Flyw. 73, 69–71.

Islamy, R.A., Hasan, V., 2020. Checklist of mangrove snails (Mollusca: Gastropoda) in south coast of pamekasan, Madura Island, East Java, Indonesia. Biodiversitas J. Biol. Divers. 21, 3127–3134.

Jamani, S., Gholizadeh, M., Patimar, R., Fathabadi, A., 2021. Identification and Abundance of Macrobenthic in Estuary of the Gharehsou River. J. Fish. 74, 31–43.

Janra, M.N., Mursyid, A., Aadrean, I.G., Ringga, M., Ikhsan, M., 2018. Shorebird surveys at the Coast of West Sumatra Province, Indonesia: 2017-2018. Stilt 72, 27–32.

Jayachandran, P.R., Nandan, S.B., Jima, M., Joseph, P., Xavier, N.D.D., Sreedevi, O.K., Prabhakaran, M.P., Joseph, K.J., 2019. Macrobenthic functional feeding groups in a microtidal monsoonal estuary (Kodungallur–Azhikode estuary, India). Reg. Stud. Mar. Sci. 25, 100444.

Joesidawati, M.I., 2018. Mollusc Communitiess at Coastal Kemantren, Paciran, Lamongan. Oceanogr. Fish. Open Access J. 6, 57–65.

Joshua, T.J., Toefy, R., Sparks, C., Kirkman, S.P., Samaai, T., 2018. Macro-benthic invertebrate assemblages in the Betty’s Bay marine protected area (Kogelberg region South Africa). Reg. Stud. Mar. Sci. 22, 1–8.

Kabir, M., Abolfathi, M., Hajimoradloo, A., Zahedi, S., Kathiresan, K., Goli, S., 2014. Effect of mangroves on distribution, diversity and abundance of molluscs in mangrove ecosystem: a review. Aquac. Aquarium, Conserv. Legis. 7, 286–300.

Kantharajan, G., Pandey, P.K., Krishnan, P., Samuel, V.D., Bharti, V.S., Purvaja, R., 2017. Molluscan diversity in the mangrove ecosystem of Mumbai, west coast of India. Reg. Stud. Mar. Sci. 14, 102–111.

Li, Q., Wang, G., Wang, H., Shrestha, S., Xue, B., Sun, W., Yu, J., 2020. Macrozoobenthos variations in shallow connected lakes under the influence of intense hydrologic pulse changes. J. Hydrol. 584, 124755.

Liu, K., Lin, H., He, X., Huang, Y., Li, Z., Lin, J., Mou, J., Zhang, S., Lin, L., Wang, J., 2019. Functional trait composition and diversity patterns of marine macrobenthos across the Arctic Bering Sea. Ecol. Indic. 102, 673–685.

Lv, W., Zhou, W., Zhao, Y., 2019. Effect of freshwater inflow on self-restoration of macrobenthic diversity in seaward intertidal wetlands influenced by reclamation projects in the Yangtze estuary, China. Mar. Pollut. Bull. 138, 177–186.

Marsden, I.D., Baharuddin, N., 2015. Gastropod growth and survival as bioindicators of stress associated with high nutrients in the intertidal of a shallow temperate estuary. Estuar. Coast. Shelf Sci. 156, 175–185.

Noh, J., Yoon, S.J., Kim, H., Lee, C., Kwon, B.-O., Lee, Y., Hong, S., Kim, J., Ryu, J., Khim, J.S., 2019. Anthropogenic influences on benthic food web dynamics by interrupted freshwater discharge in a closed Geum River estuary, Korea. Environ. Int. 131, 104981.

Opa, E.T., Kepel, R.C., Lasabuda, R., Kusen, J.D., Paruntu, C.P., Djamaluddin, R., Boneka, F.B., Mantiri, D.M.H., 2021. Ecological suitability of mangrove tourism in Mantehage Island as the outermost small island in North Sulawesi, Indonesia. Aquac. Aquarium, Conserv. Legis. 14, 120–129.

Park, J.M., Huh, S.-H., 2018. Epibenthic invertebrate fauna in the southern coast of the East Sea, Korea. J. Asia-Pacific Biodivers. 11, 217–222.

Pelletier, M., Cobb, D., Rocha, K., Ho, K.T., Cantwell, M.G., Perron, M., Charpentier, M.A., Buffum, H.W., Hale, S.S., Burgess, R.M., 2021. Benthic macroinvertebrate community response to environmental changes over seven decades in an urbanized estuary in the northeastern United States. Mar. Environ. Res. 169, 105323.

Purchon, R.D., 2013. The biology of the Mollusca. Elsevier.

Ramses, Ismarti, Amelia, F., Rozirwan, Suheryanto, 2020. Diversity and abundance of polychaetes in the west coast waters of Batam Island, Kepulauan Riau Province-Indonesia. AACL Bioflux 13, 381–391.

Ratmoko, I.A., Budianta, D., Ridho, R., Wildayana, E., Idrus, Z., Nuryamsasni, N., 2021. Analytic hierarchy process for zonation review of Sembilang National Park, Banyuasin Regency, South Sumatera Province, Indonesia, in: IOP Conference Series: Earth and Environmental Science. IOP Publishing, p. 12019.

Rehitha, T. V, Ullas, N., Vineetha, G., Benny, P.Y., Madhu, N. V, Revichandran, C., 2017. Impact of maintenance dredging on macrobenthic community structure of a tropical estuary. Ocean Coast. Manag. 144, 71–82.

Reis, A., Alves, A.T., Dórea, A., Beneli, T.M., Santos Freitas, T.S., Barros, F., 2021. Distribution and movement of the mangrove gastropod Littoraria angulifera. Estuar. Coast. Shelf Sci. 250, 107145. https://doi.org/https://doi.org/10.1016/j.ecss.2020.107145

Rekha, K., Anbalagan, S., Dinakaran, S., 2021. Distributional ecology of snails (Gastropoda: Mollusca) in seasonal ponds of Tamil Nadu, South India. Acta Ecol. Sin. 41, 410–415.

Rozirwan, Fauziyah, Wulandari, P.I., Nugroho, R.Y., Agutriani, F., Agussalim, A., Supriyadi, F., Iskandar, I., 2022. Assessment distribution of the phytoplankton community structure at the fishing ground, Banyuasin estuary, Indonesia. Acta Ecol. Sin. https://doi.org/https://doi.org/10.1016/j.chnaes.2022.02.006

Rozirwan, Iskandar, I., Hendri, M., Apri, R., Supardi, Azhar, N., Mardiansyah, W., 2019. Distribution of phytoplankton diversity and abundance in Maspari island waters, South Sumatera, Indonesia, in: IOP Conference Series: Journal of Physics. IOP Publishing, p. 012105. https://doi.org/10.1088/1742-6596/1282/1/012105

Rozirwan, Melki, Apri, R., Fauziyah, Agussalim, A., Hartoni, Iskandar, I., 2021a. Assessment the macrobenthic diversity and community structure in the Musi Estuary, South Sumatra, Indonesia. Acta Ecol. Sin. 41, 346–350. https://doi.org/https://doi.org/10.1016/j.chnaes.2021.02.015

Rozirwan, Melki, Apri, R., Nugroho, R.Y., Fauziyah, Agussalim, A., Iskandar, I., 2021b. Assessment of phytoplankton community structure in Musi Estuary, South Sumatra, Indonesia. AACL Bioflux 14, 1451–1463.

Saffian, N.S., Peng, C.T.C., Ilias, N., Hwai, A.T.S., 2020. Overview and challenges of blood cockle culture in Malaysia, in: IOP Conference Series: Earth and Environmental Science. IOP Publishing, p. 12020.

Sahidin, A., Zahidah, Z., Hamdani, H., Riyantini, I., Sewiko, R., 2018. The Biodiversity of Gastropods in Karapyak Rocky Shores, Pangandaran Region, West Java Province, Indonesia. Omni-Akuatika 14, 79–85.

Saputra, A., Nugroho, R.Y., Isnaini, R., Rozirwan, 2021. A review: The potential of microalgae as a marine food alternative in Banyuasin Estuary, South Sumatra, Indonesia. Egypt. J. Aquat. Biol. Fish. 59, 1053–1065. https://doi.org/10.21608/EJABF.2021.170654

Sarno, S., Suwignyo, R.A., Dahlan, Z., Munandar, M., Ridho, M.R., 2018. Reproductive phenology of Bruguiera sexangula (Lour.) Poir. in Berbak and Sembilang National Park, South Sumatra. Berk. Penelit. Hayati J. Biol. Res. 23, 62–69.

Sarno, Suwigyo, R.A., Dahlan, Z., Munandar, Ridho, M.R., Aminasih, N., Harmida, Armanto, M.E., Wildayana, E., 2017. The phenology of Sonneratia alba J. Smith in Berbak and Sembilang National Park, South Sumatra, Indonesia. Biodiversitas J. Biol. Divers. 18, 909–915.

Sturm, C.F., Pearce, T.A., Valdés, Á., 2006. The mollusks: a guide to their study, collection, and preservation. Universal-Publishers.

Subramanian, R., Retnamma, J., Nagarathinam, A., Loganathan, J., Singaram, P., Chandrababu, V., 2021. Seasonality of macrobenthic assemblages and the biotic environmental quality of the largest monsoonal estuary along the west coast of India. Environ. Sci. Pollut. Res. 28, 37262–37278.

Suratissa, D.M., Rathnayake, U., 2017. Effect of pollution on diversity of marine gastropods and its role in trophic structure at Nasese Shore, Suva, Fiji Islands. J. Asia-Pacific Biodivers. 10, 192–198.

Susilo, V.E., Dewi, M.I.P., Mujiono, N., Subchan, W., Prihatin, J., 2021. The diversity of Gastropoda in grati lake district pasuruan east java, in: Journal of Physics: Conference Series. IOP Publishing, p. 12008.

Weerman, E.J., Herman, P.M.J., Van de Koppel, J., 2011. Macrobenthos abundance and distribution on a spatially patterned intertidal flat. Mar. Ecol. Prog. Ser. 440, 95–103.

Wells, F.E., Sanpanich, K., Tan, S.K., Duangdee, T., 2021. The Marine and Estuarine Molluscs of Thailand. Lee Kong Chian Nat. Hist. Museum, Natl. Univ. Singapore, Singapore 195.

Wu, N., Li, F., Rousseau, D.-D., 2018. Terrestrial mollusk records from Chinese loess sequences and changes in the East Asian monsoonal environment. J. Asian Earth Sci. 155, 35–48.

Xingzhong, Y., Jianjian, L., Hong, L., 2002. Distribution pattern and variation in the functional groups of zoobenthos in the Changjiang Estuary. Acta Ecol. Sin. 22, 2054–2062.

Yan, J., Xu, Y., Sui, J., Li, X., Wang, H., Zhang, B., 2017. Long-term variation of the macrobenthic community and its relationship with environmental factors in the Yangtze River estuary and its adjacent area. Mar. Pollut. Bull. 123, 339–348.

Youssef, M., Madkour, H., Mansour, A., Alharbi, W., El-Taher, A., 2017. Invertebrate shells (mollusca, foraminifera) as pollution indicators, Red Sea Coast, Egypt. J. African Earth Sci. 133, 74–85.

Zaki, M.R.M., Zaid, S.H.M., Zainuddin, A.H., Aris, A.Z., 2021. Microplastic pollution in tropical estuary gastropods: Abundance, distribution and potential sources of Klang River estuary, Malaysia. Mar. Pollut. Bull. 162, 111866.

Zvonareva, S.S., Kantor, Y.I., Nguyen, T.T.H., Britayev, T.A., 2020. Diversity and Long-Term Dynamics of the Macrobenthos in a Mangrove Plantation and Two Natural Associations of Khanh Hoa Province, Vietnam. Biol. Bull. 47, 1115–1125.

Fig. 1. Map of sampling stations in Berbak-Sembilang National Park

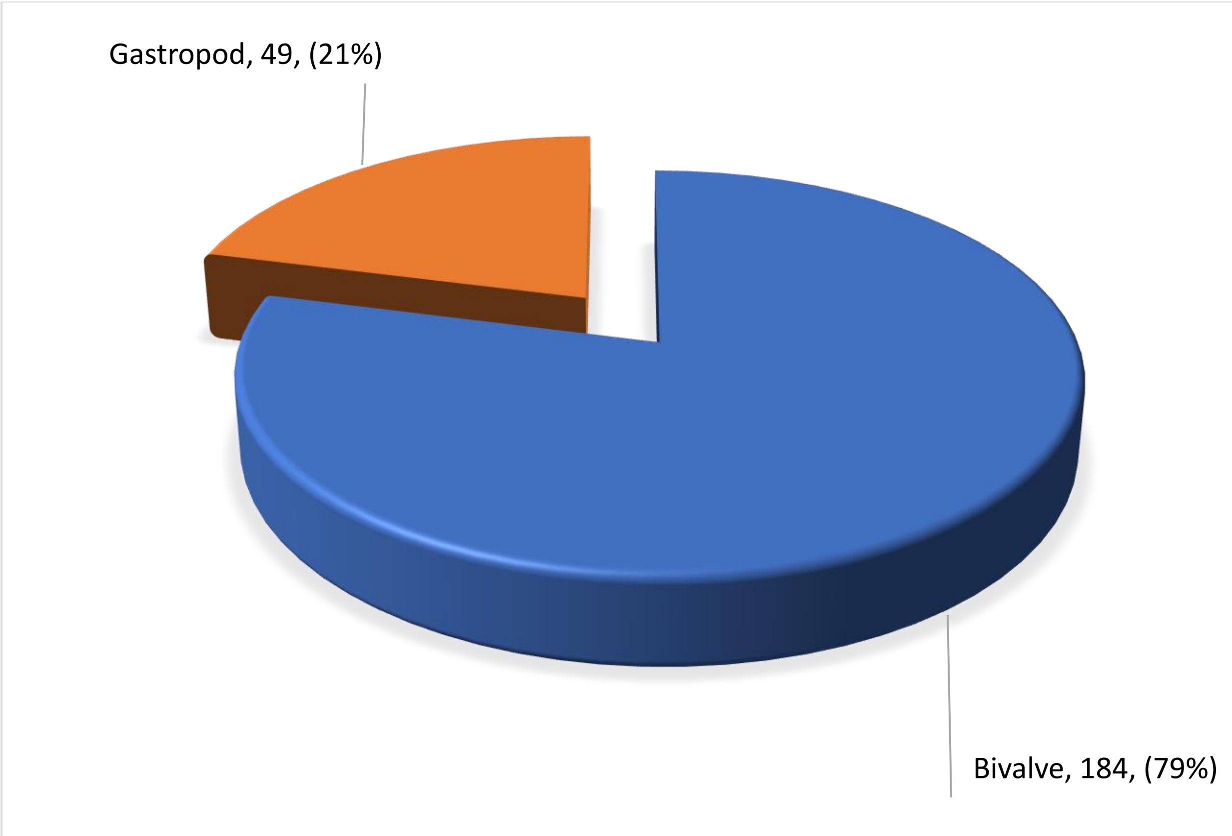

Fig. 2. Mollusks community structure in Berbak-Sembilang National Park

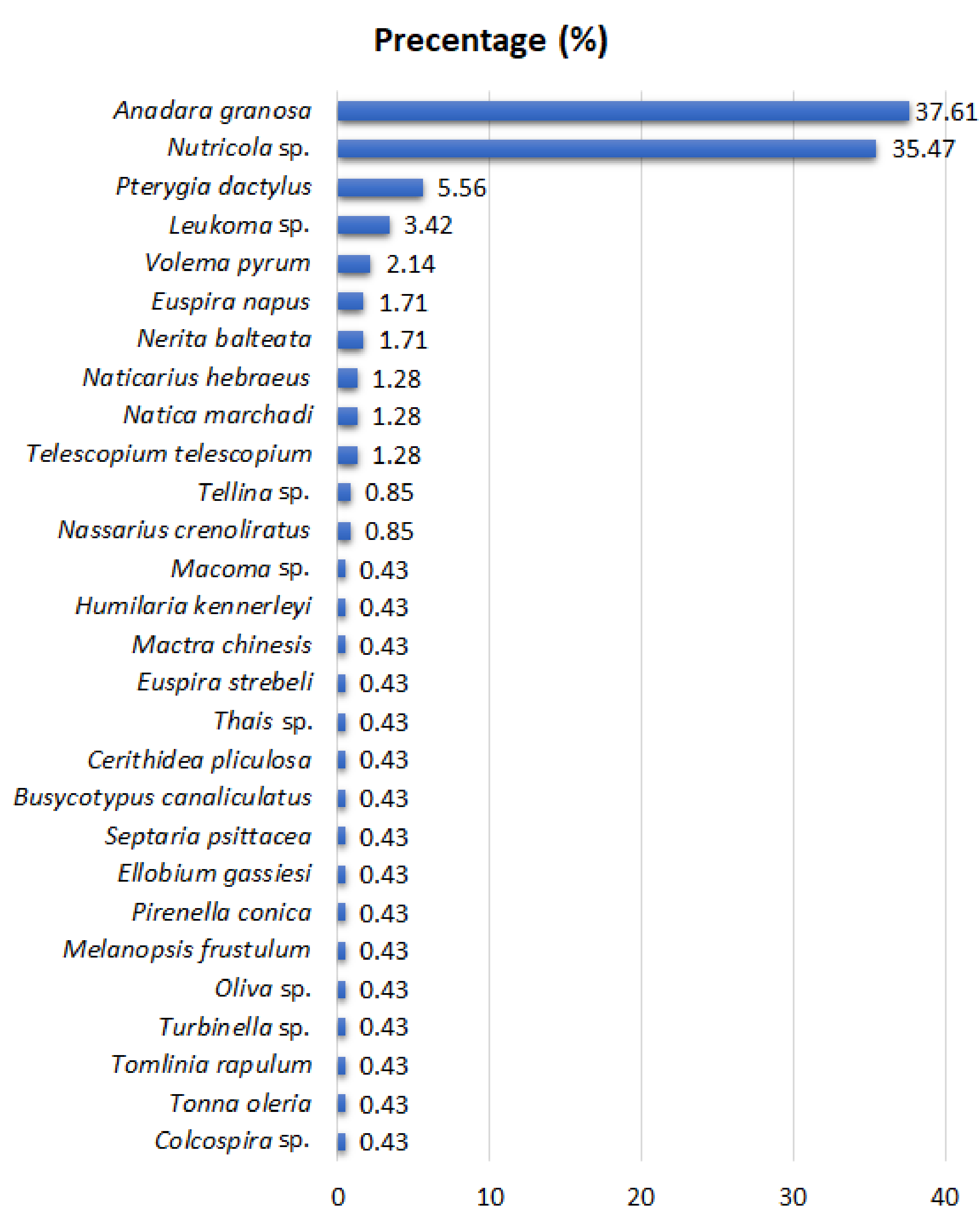

Fig. 3. Percentage of mollusks species of Berbak-Sembilang National Park

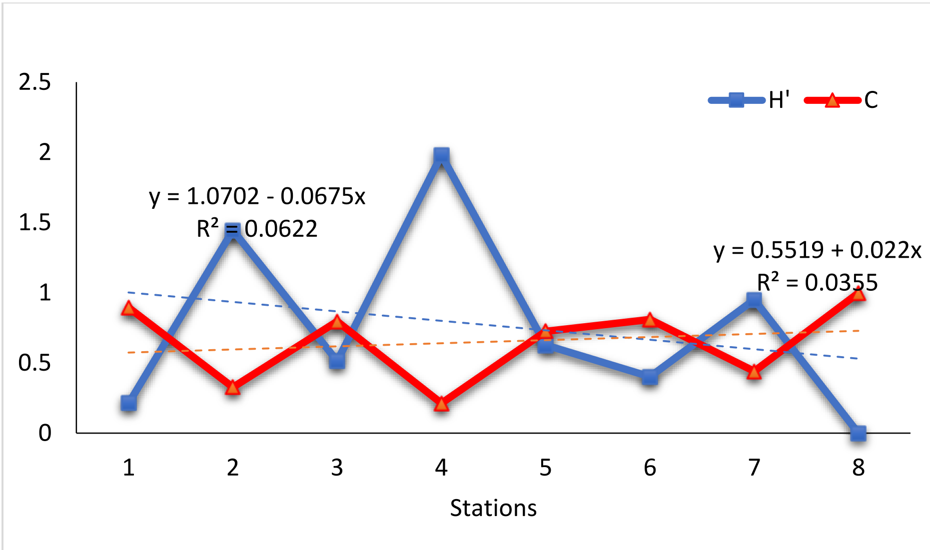

Fig. 4. Diversity index of mollusks of Berbak-Sembilang National Park

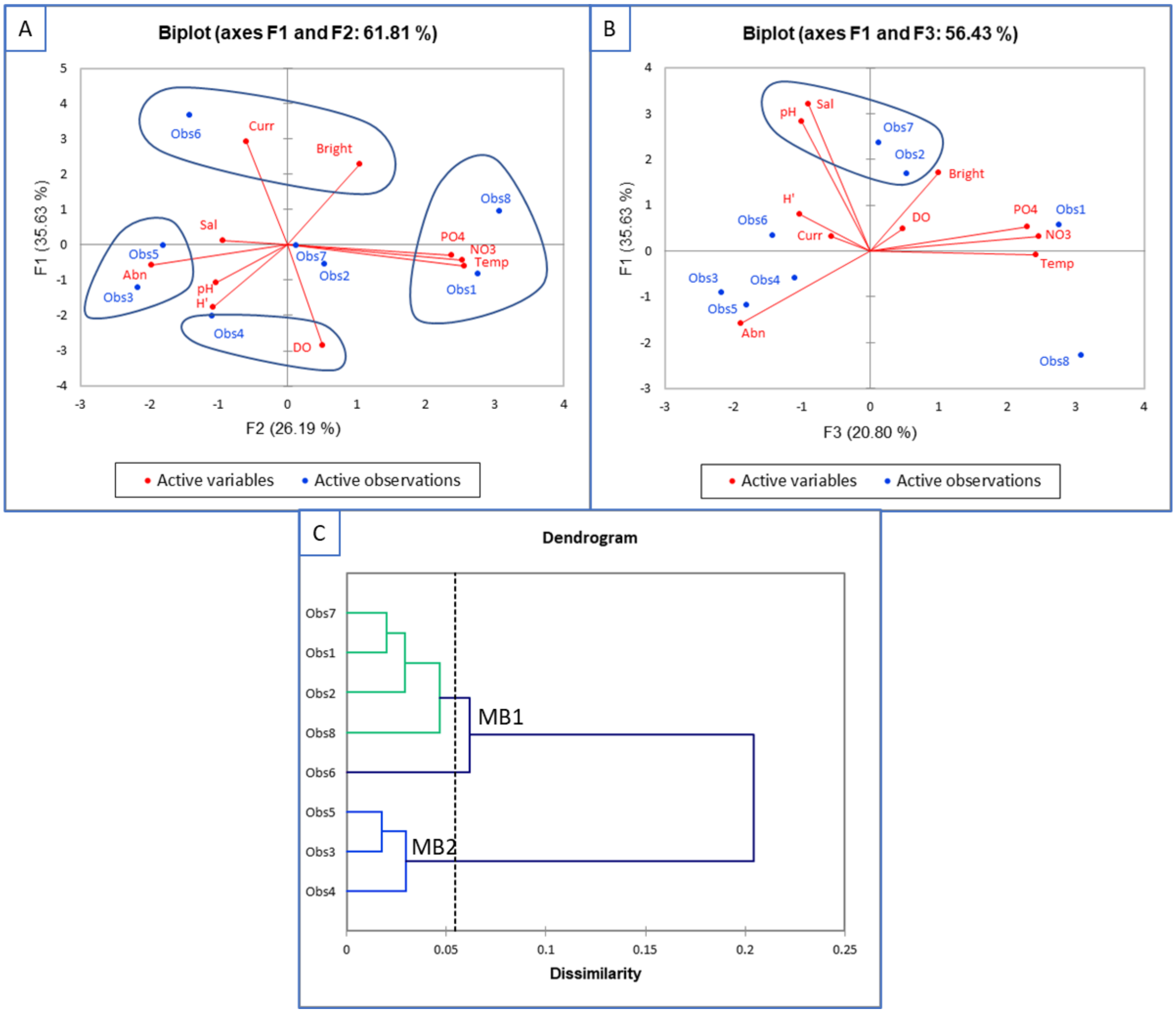

Fig. 5. Correlation between water quality parameters with mollusks abundance and diversity, (a) F1 and F2 axes; (b) F3 axes; (c) Dendrogram dissimilarity

Table 1
Water quality parameters of Berbak-Sembilang National Park

No	Water quality	Stations							
		1	2	3	4	5	6	7	8
1	pH	7.41	7.46	7.51	7.46	7.01	7.17	8.20	6.08
2	Salinity (ppt)	30.00	32.00	30.00	30.00	30.00	31.00	32.00	28.00
3	DO (mg L^{-1})	8.63	8.37	8.50	8.03	7.48	6.30	7.60	7.30
4	Temperature (^{o}C)	29.65	29.63	29.42	29.40	29.35	29.36	29.43	29.69
5	Brightness (%)	17.56	20.89	10.87	6.52	8.70	24.36	17.72	16.98
6	Current Speed (m s^{-1})	0.08	0.19	0.08	0.13	0.16	0.47	0.15	0.18
7	NO_3 (mg L^{-1})	6.67	6.20	5.45	6.24	5.53	5.66	6.23	6.69
8	PO_4 (mg L^{-1})	0.20	0.19	0.16	0.19	0.17	0.17	0.19	0.20

Table 2

Mollusks species of Berbak-Sembilang National Park

No	Class	Species	Stations							
			S1	S2	S3	S4	S5	S6	S7	S8
1	Gastropod	*Colcospira* sp.	-	+	-	-	-	-	-	-
2	Gastropod	*Nassarius crenoliratus*	-	+	-	-	+	-	-	-
3	Gastropod	*Tonna oleria*	-	+	-	-	-	-	-	-
4	Gastropod	*Tomlinia rapulum*	-	+	-	-	-	-	-	-
5	Gastropod	*Turbinella* sp.	-	+	-	-	-	-	-	-
6	Gastropod	*Oliva* sp.	-	+	-	-	-	-	-	-
7	Gastropod	*Melanopsis frustulum*	-	-	+	-	-	-	-	-
8	Gastropod	*Telescopium telescopium*	-	-	+	+	-	-	-	-
9	Gastropod	*Nerita balteata*	-	-	+	+	-	-	-	-
10	Gastropod	*Pirenella conica*	-	-	+	-	-	-	-	-
11	Gastropod	*Ellobium gassiesi*	-	-	-	+	-	-	-	-
12	Gastropod	*Euspira napus*	-	-	-	+	+	-	-	-
13	Gastropod	*Natica marchadi*	-	-	-	+	-	-	-	-
14	Gastropod	*Naticarius hebraeus*	-	-	-	+	-	-	-	-
15	Gastropod	*Septaria psittacea*	-	-	-	+	-	-	-	-
16	Gastropod	*Pterygia dactylus*	-	-	-	+++	-	-	-	-
17	Gastropod	*Busycotypus canaliculatus*	-	-	-	+	-	-	-	-
18	Gastropod	*Cerithidea pliculosa*	-	-	-	+	-	-	-	-
19	Gastropod	*Thais* sp.	-	-	-	+	-	-	-	-
20	Gastropod	*Volema pyrum*	-	-	-	+	-	-	-	-
21	Gastropod	*Euspira strebeli*	-	-	-	-	-	-	+	-
22	Bivalve	*Anadara granosa*	+	+++	+++	+++	+	+	-	-
23	Bivalve	*Leukoma* sp.	-	++	-	-	-	-	-	-
24	Bivalve	*Mactra chinesis*	-	-	+	-	-	-	-	-
25	Bivalve	*Humilaria kennerleyi*	-	-	-	+	-	-	-	-
26	Bivalve	*Tellina* sp.	-	-	-	-	+	-	-	-
27	Bivalve	*Nutricola* sp.	-	-	-	-	+++	+++	-	+++
28	Bivalve	*Macoma* sp.	-	-	-	-	-	-	+	-

Noted: - is not found, +: <50 ind m^{-2}, ++: 50-100 ind m^{-2}, and +++: >100 ind m^{-2}

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

LAPORAN PENELITIAN
PENELITIAN DASAR UNGGULAN PERGURUAN TINGGI (PDUPT) TAHUN 2

Eksplorasi Ekosistem Bentik sebagai Bioindikator Kualitas Perairan dibidang Marine Bioprospecting Sumber Pangan Alternatif pada Kawasan Strategis Pesisir Sumatera Selatan (Musi Ecosystem Project / Musi Eco Pro) (Tahun 2)

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Tanggal 12 April 2023

Universitas Sriwijaya
Desember 2023

HALAMAN PENGESAHAN LAPORAN AKHIR
SKEMA PENELITIAN DASAR UNGGULAN PERGURUAN TINGGI (PDUPT)

1. Judul Penelitian	:	Eksplorasi Ekosistem Bentik sebagai Bioindikator Kualitas Perairan dibidang Marine Bioprospecting Sumber Pangan Alternatif pada Kawasan Strategis Pesisir Sumatera Selatan (Musi Ecosystem Project / Musi Eco Pro)
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7.Jumlah Dana yang Disetujui	:	Rp. 135,717,000

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Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. **HASIL PELAKSANAAN PENELITIAN:** Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian meliputi data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

A. Biodiversitas makrobentos

Berdasarkan penelitian ini ditemukan 3 kelas makrozoobentos yaitu *Gastropoda*, *Bivalvia*, dan *Malacostraca* dengan 16 variasi spesies makrozoobentos yang berada pada empat stasiun dengan sembilan jenis didalamnya berasal pada kelas *Gastropoda*, empat jenis kelas *malacostraca*, serta tiga jenis kelas *bivalvia* (Tabel 1).

Tabel 1. Komposisi Jenis Makrozoobentos Taman Nasional Sembilang

Class/Subclass	Species	Jenis (Ind)											
		ST 1			ST 2			ST 3			ST 4		
		a	b	c	a	b	c	a	b	c	a	b	c
Bivalvia	*Anadara Granosa*	+	-	+	+	+	+	+	+	+	-	+	+
	Pilsbryconcha Exilis	-	-	-	+	-	-	-	-	-	-	-	-
	Spisula Solidissima	-	-	-	+	+	-	+	-	+	-	-	-
Gastropoda	*Babylonia Japonica*	+	-	-	+	-	-	+	+	-	-	-	-
	Cerithidea cingulata	+	+	+	-	-	-	-	-	+	+	+	+
	Cerithidea quadrata	-	+	-	-	-	-	-	-	-	-	-	-
	Littoraria Angulifera	+	-	-	-	-	-	-	-	-	+	-	-
	Nassariius limatus	-	-	-	+	+	-	-	-	+	-	-	-
	Nassarius olivaceus	-	-	-	+	+	+	+	+	-	-	-	-
	Peringia Ulvae	-	+	-	-	-	-	+	-	-	+	-	+
	Scaphella swainson	-	+	-	-	-	-	-	-	-	+	+	-
	Telescopium telescopium	-	+	+	+	-	-	+	-	-	-	-	+
Malacostraca	*Chiromantes Haematocheir*	+	-	-	-	-	-	-	-	-	-	-	+
	Macropthalmus Telescopicus	+	-	-	+	-	+	+	-	+	+	-	-
	Thalamita crenata	-	-	-	+	-	-	+	-	-	-	-	-
	Uca sp.	+	-	-	-	-	-	+	-	+	-	-	-

Keterangan:

+ : ada

- : tidak ada

a : zona pantai

b : zona intertidal

c : zona laut

Total keseluruhan makrozoobentos berdasarkan stasiun yaitu *Cerithidea cingulata* yang didapatkan yaitu sebanyak 251 individu, *Cerithidea quadrata* 1 individu, *Nassarius olivaceus* 30 individu, *Telescopium telescopium* 7 individu, *Babylonia japonica* 3 individu, *Littoraria angulifera* 5 individu, *Nassarius limatus* 5 individu, *Scaphella swainson* 1 individu, *Peringia ulvae* 4 individu, *Chiromantes haematocheir* 3 individu, *Uca* sp. 10 individu, *Macropthalmus telescopicus* 11 individu, *Thalamita crenata* 2 individu, *Anadara granosa* 103 individu, *Spisula solidissima* 4 individu, *Pilsbryoconcha exilis* 2 individu.

Kelimpahan makrozoobentos berdasarkan hasil penelitian di Pesisir Taman Nasional Sembilang bervariasi antar stasiun, yaitu berkisar 2-222 ind/m^2 (Tabel 2).

Tabel 2. Kelimpahan Individu Makrozoobentos pada Lokasi Penelitian

Class/Subclass	Species	Kelimpahan individu (Ind/m^2)											
		ST 1			ST 2			ST 3			ST 4		
		a	b	c	a	b	c	a	b	c	a	b	c
Bivalvia	*Anadara Granosa*	0	0	0	17	15	5	20	16	27	0	1	1
	Pilsbryconcha Exilis	0	0	0	2	0	0	0	0	0	0	0	0
	Spisula Solidissima	0	0	0	1	0	0	1	0	1	0	0	0
Gastropoda	*Babylonia Japonica*	2	0	0	0	0	0	0	0	0	0	0	0
	Cerithidea cingulata	1	5	219	0	0	0	0	0	7	1	1	17
	Cerithidea quadrata	0	1	0	0	0	0	0	0	0	0	0	0
	Littoraria Angulifera	4	0	0	0	0	0	0	0	0	1	0	0
	Nassariius limatus	0	0	0	2	1	0	0	0	2	0	0	0
	Nassarius olivaceus	0	0	0	13	8	2	2	6	0	0	0	0
	Peringia Ulvae	0	1	0	0	0	0	2	0	0	1	0	0
	Scaphella swainson	0	1	0	0	0	0	0	0	0	0	0	0
	Telescopium telescopium	0	3	3	0	0	0	0	0	0	0	0	1
Malacostraca	*Chiromantes Haematocheir*	3	0	0	0	0	0	0	0	0	0	0	1
	Macropthalmus Telescopicus	5	0	0	3	0	0	0	0	1	1	0	0
	Thalamita crenata	0	0	0	1	0	0	1	0	0	0	0	0
	Uca sp.	9	0	0	0	0	0	0	0	0	0	0	0
Total		24	11	222	39	25	7	27	22	38	4	2	20

Keterangan: Zona pantai (a), Zona intertidal (b), Zona laut (c)

Biodiversitas makrozoobentos di suatu ekosistem dapat digunakan sebagai indikator status kesehatan ekosistem tersebut. Struktur komunitas makrozoobentos terdiri dari dominasi (C), keanekaragaman (H'), serta keseragaman (E). Biodiversitas dari jenis makrozoobentos dapat dilihat Indeks Keanekaragaman (H'), Indeks Keseragaman (E), Indeks Dominansi (C), merupakan kajian yang digunakan untuk menduga kondisi suatu lingkungan perairan berdasarkan komponen biologis (1). Indeks biodiversitas makrozoobentos di Taman Nasional Sembilang disajikan pada Tabel 3.

Keanekaragaman biota yang hidup dalam ekosistem bisa mengambarkan kesuburan dan juga kualitas perairan ekosistem tersebut. Suatu lingkungan yang memiliki Indeks Keanekaragaman yang kecil mengambarkan kondisi lingkungan yang belum cukup kompleks untuk biota hidup dalam lingkungan tersebut (2). Tinggi rendahnya tingkat Keanekaragaman dipengaruhi oleh kesuburan habitat yang dapat mendukung kehidupan setiap spesies yang menempati tempat tersebut. Nilai indeks Keanekaragaman (H') komunitas moluska di Perairan Taman Nasional Sembilang berdasarkan persamaan Shannon-Wiener bisa dilihat pada (Tabel 3).

Nilai indeks keanekaragaman tertinggi berada pada stasiun 1 zona pantai (1a) dengan nilai indeks 1,6 yaitu berdasarkan data diperoleh 7 spesies yang berbeda dan jumlah yang cukup merata, sedangkan indeks keanekaragaman terendah berada pada stasiun 1 zona pantai (1c) dengan nilai indeks 0,1 yaitu berdasarkan data komposisi jenis memiliki 3 spesies dengan jumlah yang jauh berbeda. Menurut (3) keanekaragaman mengekspresikan variasi spesies yang ada dalam suatu ekosistem, ketika suatu ekosistem memiliki indeks keanekaragaman yang tinggi maka ekosistem tersebut cenderung seimbang. Sebaliknya, jika suatu ekosistem memiliki nilai indeks yang rendah maka ekosistem tersebut dalam keadaan tertekan atau terdegradasi.

Jumlah spesies *Cerithidea cingulata* yang mendominasi pada stasiun 1 dapat disebabkan oleh banyaknya bahan organik yang terkandung pada sedimen. Menurut (4) populasi *Cerithidea cingulata* dapat meledak jika pada suatu perairan terdapat banyak endapan bahan-bahan organik, sehingga populasinya dalam jumlah besar dapat menjadi bioindikator tingkat pencemaran organik di suatu perairan.

Tabel 3. Biodiversitas Makrozoobentos Taman Nasional Sembilang

Stasiun		Keanekaragaman (H')		Keseragaman (E)		Dominansi (C)	
		Indeks	Kriteria	Indeks	Kriteria	Indeks	Kriteria
1	a	1,6	sedang	0,83	tinggi	0,2	tidak ada
	b	1,3	sedang	0,80	tinggi	0,3	tidak ada
	c	0,1	rendah	0,07	rendah	1,0	ada
2	a	1,5	sedang	0,71	tinggi	0,3	tidak ada
	b	0,8	rendah	0,59	sedang	0,5	tidak ada
	c	0,7	rendah	0,66	tinggi	0,6	ada
3	a	1,0	sedang	0,48	sedang	0,6	ada
	b	0,6	rendah	0,58	sedang	0,6	ada
	c	0,9	rendah	0,51	sedang	0,5	tidak ada
4	a	1,5	sedang	0,95	tinggi	0,2	tidak ada
	b	1,0	sedang	0,91	tinggi	0,4	tidak ada
	c	0,6	rendah	0,36	rendah	0,8	ada

Keterangan: Zona pantai (a), Zona intertidal (b), Zona laut (c)

B. Tingkat Pencemaran Akibat Dampak antropogenik Pada Makrobentos

Komponen yang dinilai dalam mempelajari akumulasi logam berat terdiri dari air, sedimen, dan organisme dasar makrobentos. Logam berat yang dinilai (Pb, Hg, Cu, dan Cd) dapat berasal dari berbagai sumber eksternal dan internal kolam tambak. Menariknya bahwa pengukuran logam berat Cd penelitian ini berada dibawah batas nilai mutu kemampuan pengukuran spektrofotometri yang ditunjukkan nilai negatif. Selain itu, akumulasi logam berat Cu di air juga menghasilkan nilai yang lebih rendah dari yang bisa diukur alat (Tabel 4).

Nilai akumulasi logam berat Pb dengan rata-rata paling tinggi terdeteksi pada sedimen yaitu 8.929 ± 2.236 ppm dan paling rendah yaitu *T. telescopium* yaitu 0.026 ± 0.034 ppm. Akumulasi logam berat Hg paling tinggi yaitu *N. violacea* dengan nilai rata-rata akumulasi 0.197 ± 0.032 ppm, sedangkan paling rendah yaitu air dengan nilai rata-rata 0.004 ± 0.003 ppm. Logam berat Cu hanya terdapat pada sedimen dan kedua spesies makrobentos, paling tinggi di sedimen yaitu 2.724 ± 0.603 ppm dan paling rendah di *N. violacea* yaitu 0.006 ± 0.003 ppm.

Tabel 4. Pengukuran logam berat Pb, Hg, Cu, dan Cd di lingkungan tambak

Accumulations	Heavy metals (ppm)	Observation stations					Average (Stdev)
		1	2	3	4	5	
water	Pb1	0.026	0.013	0.088	0.056	0.046	0.046 ± 0.029
	Hg1	0.001	0.005	0.008	0.003	0.001	0.004 ± 0.003
	Cu1	-0.035	-0.045	-0.027	-0.050	-0.046	-0.041 ± 0.009
	Cd1	-0.229	-0.019	-0.022	-0.020	-0.019	-0.062 ± 0.093
sediment	Pb2	11.630	6.014	10.670	8.210	8.120	8.929 ± 2.236
	Hg2	0.122	0.129	0.160	0.125	0.107	0.129 ± 0.019
	Cu2	3.510	2.450	3.220	2.280	2.160	2.724 ± 0.603
	Cd2	-0.023	-0.022	-0.022	-0.025	-0.024	-0.023 ± 0.001

N. violacea	Pb3	0.001	0.120	0.330	0.003	0.001	0.091 ± 0.143
	Hg3	0.225	0.205	0.227	0.176	0.153	0.197 ± 0.032
	Cu3	0.011	0.005	0.006	0.002	0.004	0.006 ± 0.003
	Cd3	-0.017	-0.006	-0.014	-0.012	-0.012	-0.012 ± 0.004
T. telescopium	Pb4	0.002	0.063	0.063	0.001	0.001	0.026 ±0.034
	Hg4	0.001	0.430	0.183	0.135	0.071	0.164 ± 0.164
	Cu4	0.014	0.031	0.020	0.020	0.020	0.021 ± 0.006
	Cd4	-0.013	-0.014	-0.012	-0.007	-0.009	-0.011 ± 0.003

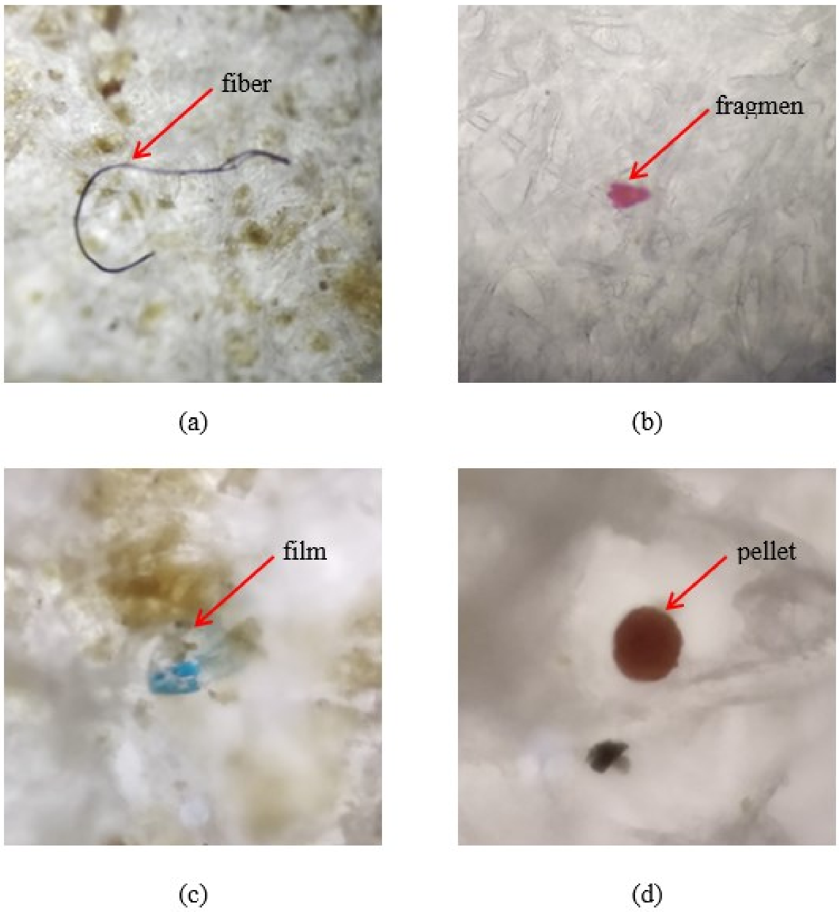
Identifikasi makrobentos dilakukan pada biota khusus makrozobentos yang dominan ditemukan di daerah penelitian yaitu *Anadara granosa* dan *Cerithidea cingulata.* Konsentrasi logam berat Pb dan Cu pada sedimen dan makrobentos disajikan pada Tabel 5. Logam berat dianalisis menggunakan metode *Atomic Aborption Spectrofotometer* (AAS), hasil konsentrasi kemudian dibandingkan dengan baku mutu yang telah ditetapkan.

Tabel 5. Konsentrasi logam berat Pb dan Cu pada sedimen dan makrobentos

Stasiun	Logam Pb (mg/kg)		Logam Cu (mg/kg)	
	Sedimen	Biota	Sedimen	Biota
1	11,5	0,0012	5,08	0,0075
2	11,3	0,005	5,21	0,0147
3	10,5	0,0001	5,46	0,0037
4	10,51	0,0005	5,33	0,0051

Nilai logam berat Pb tinggi di stasiun 1 dan stasiun 2, sesuai dengan letak stasiun yang lebih dekat dengan estuari, nilai pH yang rendah (6,5 - 6,7) juga akan mengakibatkan penurunan pH disuatu perairan dan dapat menyebabkan meningkat konsentrasi logam berat, karena logam berat akan mudah larut dalam kondisi asam (5). Konsentrasi Cu pada sedimen di wilayah penelitian relatif konstan, nilai logam Cu tertinggi pada stasiun 3 dan terendah pada stasiun 1, tetapi nilai logam berat Cu secara keseluruhan hampir sama dan tergolong sangat kecil, ini dikarnakan faktor perariran di setiap stasiun itu hampir sama. Faktor lain yang menyebabkan tinggi logam berat Pb dibandingkan dengan logam berat Cu disebabkan logam berat Pb memiliki nomor 34 atom yang lebih besar dibandingkan logam berat Cu. Logam berat Pb memiliki nomor atom sebesar 82 dan Cu nomor atomnya sebesar 29. Logam berat yang memiliki nomor atom lebih besar memiliki kemampuan cepat mengendap ke sedimen (6).

Berdasarkan hasil identifikasi ditemukan empat jenis mikroplastik yang terdapat pada sampel sedimen dan biota yang telah diamati. Kemudian mikroplastik yang ditemukan dikelompokkan jenisnya berdasarkan observasi visual, yaitu dengan melihat bentuk, ukuran, dan warna dari partikel mikroplastik (7).

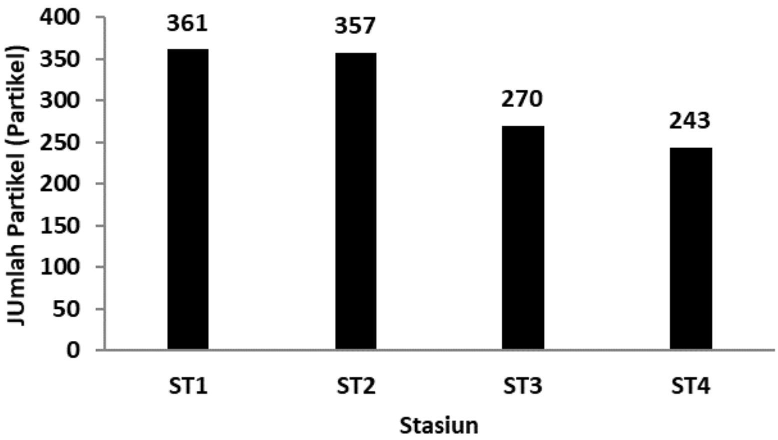


Gambar 1. Hasil Identifikasi Jenis Mikroplastik (a. fiber; b. fragmen; c. film; d. pelet)

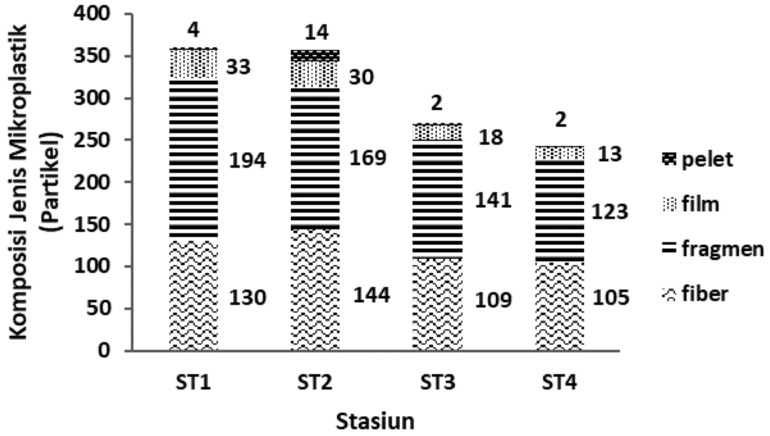
Gambar (a) merupakan jenis mikroplastik fiber, jenis mikroplastik ini berbentuk seperti serat atau benang halus berukuran panjang berwarna biru, merah dan hitam (8). Jenis ini biasanya berasal dari hasil pencucian pakaian maupun benang pancing atau jaring nelayan yang terdegradasi (9). Gambar (b) merupakan mikroplastik jenis fragmen. Jenis ini ditemukan dalam bentuk pecahan tebal tidak beraturan dan bertepi tajam biasanya terdiri dari warna merah, kuning, biru, coklat dan hijau (10). Mikroplastik ini berasal dari sampah plastik yang lebih besar yang terdegradasi atau terurai menjadi pecahan yang lebih kecil. Gambar (c) adalah mikroplastik jenis film. Sampel, jenis ini terlihat seperti fragmen, tetapi pecahannya lebih tipis, fleksibel, dan cenderung transparan (11). Mikroplastik bentuk film berasal dari fragmentasi kantong plastik atau plastik kemasan yang terurai dan memiliki densitas rendah (12). Gambar (d) pellet atau granule, jenis ini dapat ditemukan dalam bentuk memanjang seperti pellet dan bulat. Pada gambar ditemukan jenis pellet berbentuk bulat (13). Mikroplastik jenis pellet biasanya berasal dari biji plastik yang akan diproduksi. Selain itu juga dapat berasal dari sumber mikroplastik yang terdegradasi di alam.

Hasil pengamatan mikroplastik pada sedimen di semenanjung Taman Nasional Sembilang didapatkan sebanyak 4 jenis mikroplatik yaitu jenis fiber fragmen, film, dan pellet. Hasil yang didapatkan sama dengan hasil penelitian yang dilaksanakan oleh (14) di Perairan Pantai Kecamatan Pandan, Kabupaten Tapanuli Tengah, Provinsi Sumatera Utara dan penelitian yang dilaksanakan oleh (15) di Bagian Muara Sungai Musi, Provinsi Sumatera Selatan.

Hasil pengamatan kelimpahan mikroplastik pada sedimen di empat titik stasiun berbeda yang berlokasi di Taman Nasional Sembilang di jumlahkan dan dikelompokkan berdasarkan jenisnya. Dapat dilihat jumlah mikroplastik (Gambar 2) dan komposisi yang didapat (Gambar 3) disajikan dalam bentuk diagram batang. Komposisi kelimpahan mikroplastik pada sedimen yang diambil dari lokasi penelitian terdiri dari empat jenis.



Gambar 2. Jumlah Mikroplastik Per Stasiun pada Sedimen



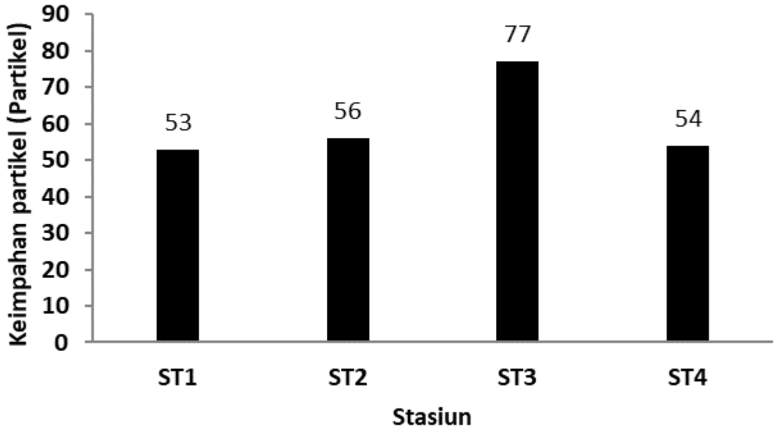
Gambar 3. Komposisi Jenis Mikroplastik Per Stasiun pada Sedimen

Hasil kelimpahan mikroplastik di sedimen (Gambar 2) didapatkan dari hasil identifikasi mikroplastik pada setiap sampel yang kemudian dicatat setiap jumlah mikroplastik yang ditemukan. Kelimpahan tertinggi (361 partikel/g) terdapat pada stasiun 1 yaitu daerah muara Sungai Barong Kecil. Tingginya kelimpahan mikroplastik diduga disebabkan oleh faktor lingkungan seperti arus. Menurut (16) pembelokan arus dan gelombang membantu distribusi sampah dan partikel-partikel lain di perairan. Aktivitas manusia juga mempengaruhi pergerakan sampah di perairan. Berdasarkan letaknya, stasiun 1 dengan muara Sungai Banyuasin dan muara Sungai Musi.

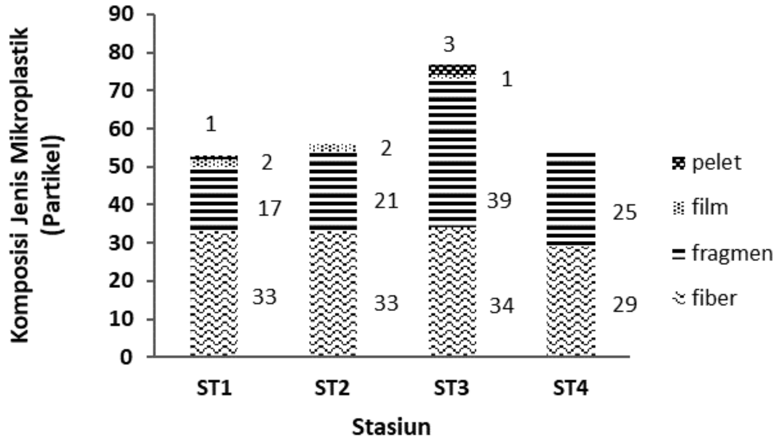
Komposisi mikroplastik yang didapatkan dari hasil identifikasi terdiri dari beberapa jenis (Gambar 3). Terdapat empat jenis mikroplastik yang berhasil diidentifikasi diantaranya fiber, fragmen, film dan pellet. Jenis yang dominan di temukan pada setiap stasiunnya ialah fragmen. Kelimpahan jenis fragmen pada setiap stasiun diantaranya; stasiun 1 (194 partikel/gr), stasiun 2 (169 partikel/gr), stasiun 3 (141 partikel/gr), dan stasiun 4 (123 partikel/gr).

Berdasarkan grafik diatas dapat dilihat bahwa kelimpahan tertinggi terdapat pada mikroplastik jenis fragmen yaitu sebanyak 617 partikel/gr. Kelimpahan terbanyak kedua didominasi oleh jenis fiber yaitu sebanyak 478 partikel/gr. Kelimpahan mikroplastik terkecil terdapat pada jenis pellet dengan kelimpahan sebanyak 22 partikel/gr. Kelimpahan tertinggi pada jenis fragmen diduga disebabkan oleh massa jenisnya yang besar sehingga partikel fragmen tersebut tenggelam dan terendapkan pada sedimen hal ini dipengaruhi oleh sumber fragmen yang berasal dari pelapukan sampah plastik (14).

Kelimpahan mikroplastik pada biota berkisar diantara 53-77 Partikel/gr (Gambar 4). Kelimpahan mikroplastik pada stasiun 1 menunjukkan nilai yang paling kecil yaitu sebanyak 53 partikel/gr. Kelimpahan mikroplastik pada stasiun 2 terdapat sebanyak 56 partikel/gr. Kelimpahan mikroplastik pada stasiun 3 menunjukkan nilai kelimpahan yang paling tinggi yaitu sebanyak 77 partikel/gr. Kelimpahan mikroplastik pada stasiun 4 sebanyak 54 partikel/gr. Komposisi kelimpahan jenis mikroplastik pada sampel biota yang ditemukan di perairan Taman Nasional Sembilang terdiri atas beberapa jenis mikroplastik (Gambar 5). Komposisi mikroplastik dominan disusun oleh jenis fiber dan fragmen.



Gambar 4. Jumlah Mikroplastik Per Stasiun pada Biota



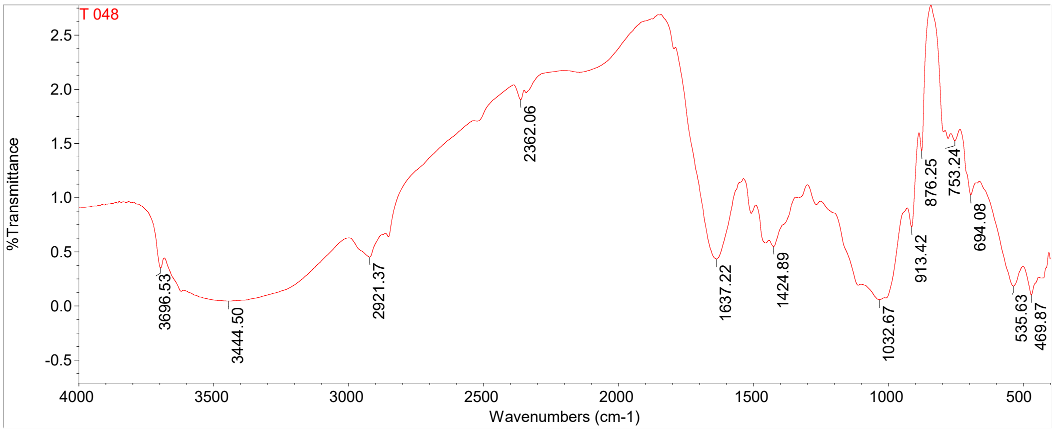
Gambar 5. Komposisi Jenis Mikroplastik Per Stasiun pada Biota

Kelimpahan jenis mikroplastik yang ditemukan pada setiap stasiun dinyatakan dalam satuan partikel/gr. Nilai tersebut menunjukkan jumlah partikel mikroplastik yang terkandung di dalam 10 gr berat basah dari jaringan lunak biota. Stasiun 1 dan 2 diwakili oleh gastropoda jenis Siput Lumpur (*Cerithidea cingulata*), stasiun 3 dan 4 diwakili oleh bivalvia jenis Kerang Darah (*Anadara granosa*). Kelimpahan mikroplastik pada stasiun 1 (53 partikel) dan 2 (56 partikel) dari sampel biota *Cerithidea cingulata* menunjukkan bahwa komposisinya didominasi oleh jenis fiber dan fragmen. Kelimpahan mikroplastik pada stasiun 3 dan 4 diambil dari sampel biota Kerang Darah (*Anadara granosa*). Kelimpahan tertinggi ditemukan pada stasiun 3. Hasil menunjukkan bahwa sampel pada stasiun 3 mengandung mikroplastik sebanyak 77 partikel. Kelimpahan mikroplastik ini didominasi oleh jenis fragmen (39 partikel/g).

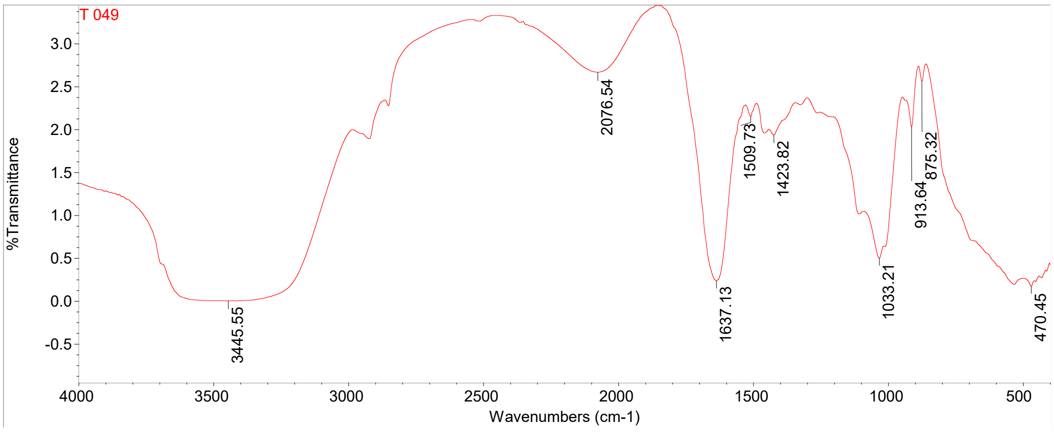
Nilai kelimpahan yang terdapat pada masing-masing jenis pada setiap stasiun cukup timpang. Kelimpahan mikroplastik jenis fiber dan fragmen mencapai 100 partikel/gr sedangkan untuk jenis film dan pellet kelimpahannya hanya dibawah 10 partikel/gr. Jenis fiber cenderung tipis dan ringan, hal tersebut menyebabkan jenis ini mengapung pada kolom perairan. Berdasarkan pernyataan (12) mikroplastik jenis fiber umumnya berasal dari pemukiman penduduk, jenis ini biasanya ditemukan di pinggiran pantai. Sedangkan jenis fragmen memiliki massa jenis yang besar sehingga cenderung terendapkan di substrat perairan (10).

Gastropoda merupakan biota *deposit feeder* yang mencari makan dengan menyedot. Gastropoda tidak dapat membedakan makanannya dan akan memakan apa saja yang datang, sehingga rentan menelan mikroplastik (17). Sedangkan Kerang merupakan organisme *filter feeder* yang memiliki kebasaan menyaring makanan dari susbtrat (18). Mikroplastik memiliki ukuran yang kecil sehingga mudah mengontaminasi biota pada perairan seperti gastropoda dan bivalvia. Mikroplastik yang tidak sengaja tertelan akan menyumbat saluran pencernaan, menyebabkan gangguan dalam reproduksi, dan menghambat pertumbuhan biota tersebut.

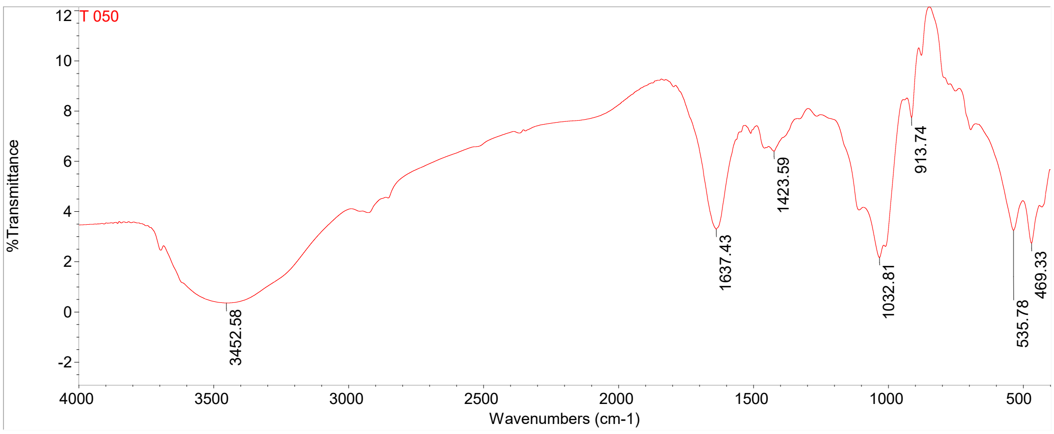
Hasil identifikasi mikroplastik menggunakan mikroskop dilanjutkan dengan identifikasi jenis polimernya menggunakan metode *Fourier Transform Infrared* (FT-IR). Grafik hasil pembacaan polimer mikroplastik pada sampel sedimen dan biota menggunakan alat FT-IR disajikan pada gambar dibawah ini.



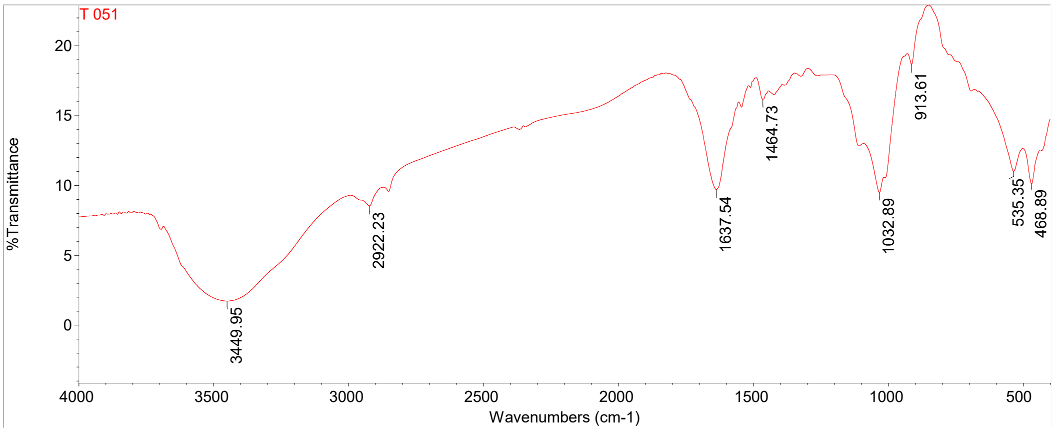
Gambar 6. Grafik Hasil FTIR Sampel Sedimen Stasiun 1



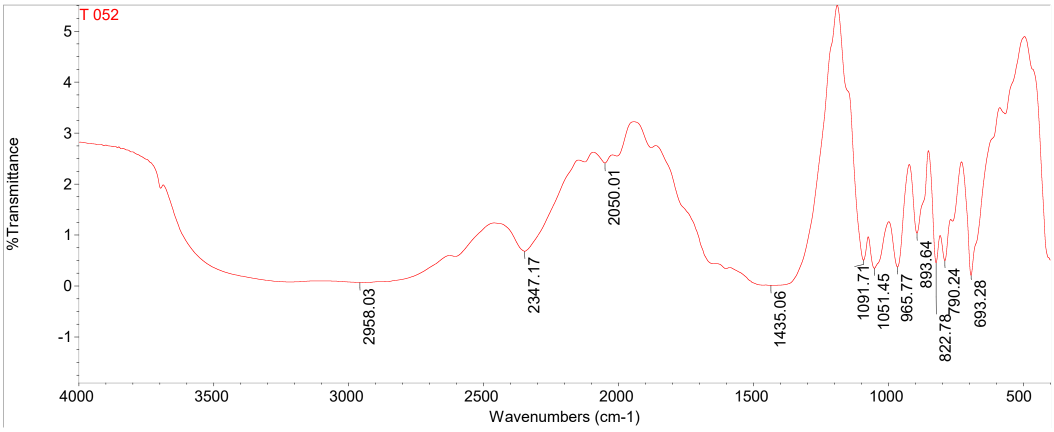
Gambar 7. Grafik Hasil FTIR Sampel Sedimen Stasiun 2



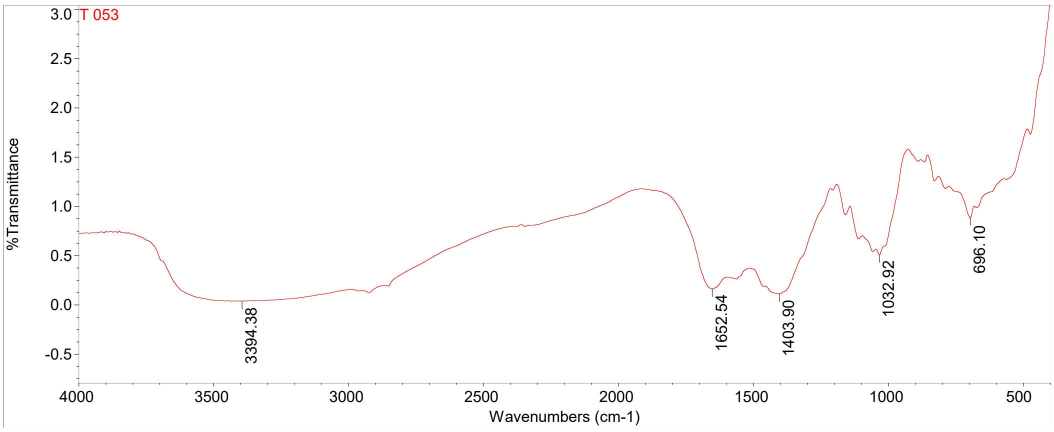
Gambar 8. Grafik Hasil FTIR Sampel Sedimen Stasiun 3



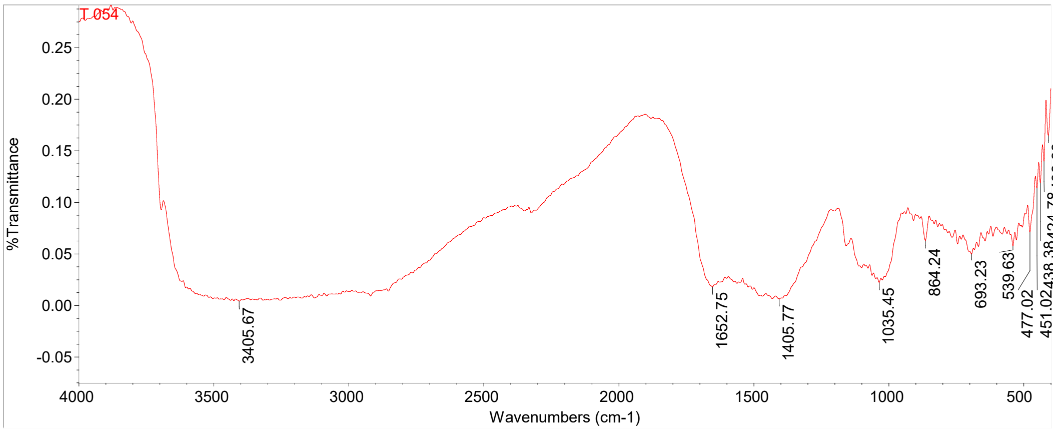
Gambar 9. Grafik Hasil FTIR Sampel Sedimen Stasiun 4



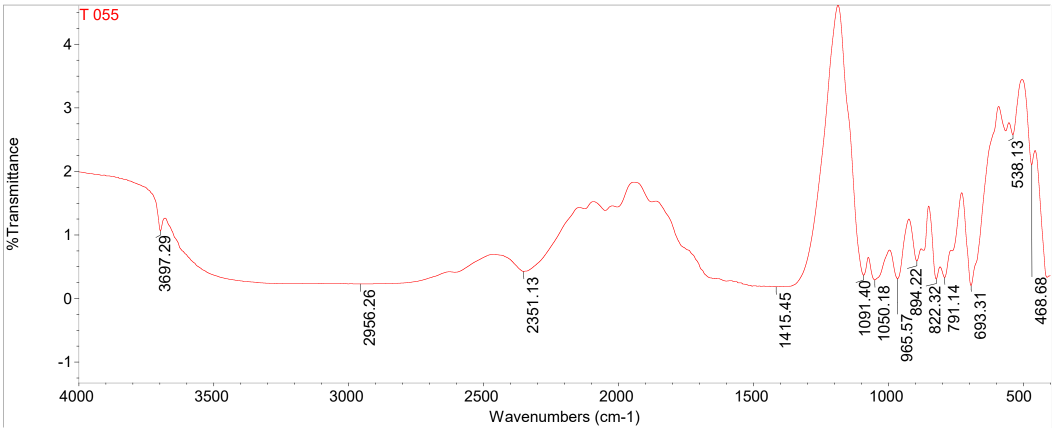
Gambar 10. Grafik Hasil FTIR Sampel Biota Stasiun 1



Gambar 11. Grafik Hasil FTIR Sampel Biota Stasiun 2



Gambar 12. Grafik Hasil FTIR Sampel Biota Stasiun 3



Gambar 13. Grafik Hasil FTIR Sampel Biota Stasiun 4

Hasil nilai serapan keberadaan puncak (*peak*) yang terdapat pada grafik kemudian ditampilkan pada tabel 6 dan 7 beserta jenis ikatan kimianya.

Tabel 6. Hasil Uji FT-IR pada Sampel Sedimen

Stasiun 1 (cm^{-1})	Stasiun 2 (cm^{-1})	Stasiun 3 (cm^{-1})	Stasiun 4 (cm^{-1})	Jenis Ikatan	Jenis Polimer
3696,53 3444,50	- 3445,55	- 3452,58	- 3449,95	OH stretch	LDPE
2921,37	-	-	2922,23	CH stretch	PE & PP
2362,06	-	-	-	-	-
-	2076,54	-	-	-	-
1637,22 -	1637,13 1509,73	1637,43 -	1637,54 -	NH bend	PA
1424,89	1423,82	1423,59	1464,73	CH_2 bend	EVA, ABS & PVC
1032,67	1033,21	1032,81	1032,89	C-F	PTFE
913,42	913,64	913,74	913,61	*Aromatic* CH *in plane bend*	PE
876,25 753,24	875,32 -	- -	- -	C-CL	PS
694,08	-	-	-	*Aromatic* CH *out of plane bend*	PE
535,63 469,87	- 470,45	535,78 466,33	535,35 468,89	SS stretch	*polisulfida*

Tabel 7. Hasil Uji FT-IR pada Sampel Biota

Stasiun 1 (cm^{-1})	Stasiun 2 (cm^{-1})	Stasiun 3 (cm^{-1})	Stasiun 4 (cm^{-1})	Jenis Ikatan
-	-	-	3697,29	
-	-	3405,67	-	OH stretch
-	3394,38	-	-	
2959,03	-	-	2956,26	CH stretch
2347,17	-	-	2351,13	
2050,01	-	-	-	
-	1652,54	1652,75	1637,54	NH bend
1435,06	1403,90	1405,77	1415,45	CH_2 bend
1091,71	1032,92	1036,45	1091,40	C-F
965,77	-	-	965,57	*Aromatic* CH *in plane bend*
893,64	-	864,24	894,22	C-CL
790,24	-	-	791,14	
693,28	696,10	693,23	693,31	*Aromatic* CH *out of plane bend*
-	-	539,63	538,13	SS stretch
-	-	477,02	468,68	

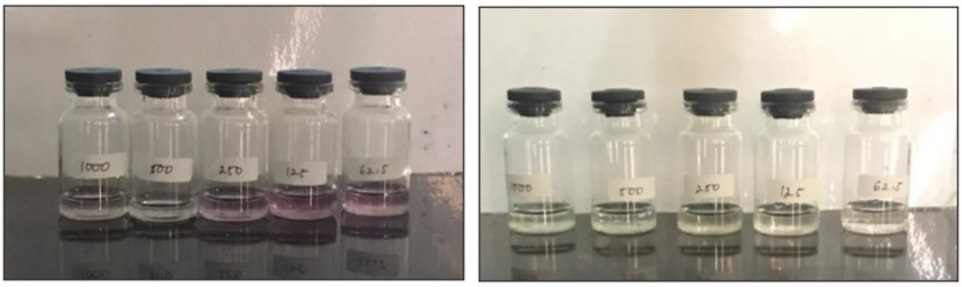
Tabel 6 menunjukkan nilai serapan puncak FT-IR yang didapatkan pada sampel sedimen. Sedangkan Tabel 7 menunjukkan nilai serapan yang di dapat pada sampel biota. Berdasarkan kedua tabel tersebut dapat dilihat beberapa nilai puncak (*peak*). Nilai 3696,53 cm^{-1} dan 3444,50 cm^{-1} (stasiun 1 sedimen), 3445,55 cm^{-1} (Stasiun 2 sedimen), 3452,58 cm^{-1} (stasiun 3 sedimen), 3449,95 cm^{-1} (stasiun 4 sedimen, 3394,38 cm^{-1} (stasiun 2 biota), 3405,67 cm^{-1} (stasiun 3 biota), dan 3697,29 cm^{-1} (stasiun 4 biota) menunjukkan nilai dari jenis ikatan OH stretch (19). Didukung oleh (20) yang menyatakan bahwa panjang *peak* antara 3600-3200 cm^{-1} menunjukkan nilai kelompok OH.

Jenis ikatan OH menunjukkan jenis polimer *plastik Low Density Polyethylene* (LDPE). Polimer berjenis LDPE biasanya digunakan sebagai bahan baku produk kemasan plastik, kantong plastik dan tutup plastik. Hal ini sesuai dengan tingginya jenis fragmen yang ditemukan pada stasiun penelitian. Mikroplastik jenis fragmen diduga berasal dari jenis LDPE yang terdegradi seperti tutup botol plastik. Jenis ikatan CH stretch dan C-C stretch diinterpretasikan dengan panjang serapan 2921,37 cm^{-1} (stasiun 1 sedimen), 2922,23 cm^{-1} (stasiun 4 sedimen), 2959,03 cm^{-1} (stasiun 1 biota), dan 2956,26 cm^{-1} (stasiun 4 biota). Gugus fungsi ini menunjukkan jenis polimer *polyethylene* (PE) dan *polypropylene* (PP). Ikatan CH merupakan penyusun utama dari jenis polimer PE dan PP. jenis mikroplastik PE biasanya digunakan sebagai bahan baku dari kantong plastik, bungkus deterjen, botol shampoo. Polimer *Polypropylene* (PP) biasanya dapat ditemukan sebagai bahan pembuatan tutup botol, sedotan, tali dan karpet (21).

Panjang puncak (*peak*) serapan yang didapatkan selanjutnya adalah 1637,22 cm^{-1} (stasiun 1 sedimen), 1637,13 dan 1509,73 cm^{-1} (stasiun 2 sedimen), 1637,43 cm^{-1} (stasiun 3 sedimen), 1637,54 cm^{-1} (stasiun 4 sedimen), 1652,54 cm^{-1} (stasiun 2 biota), 1652,75 cm^{-1} (stasiun 3 biota), dan 1637,54 cm^{-1} (stasiun 4 biota). Nilai serapan tersebut menunjukkan ikatan kimia NH stretch yang merupakan struktur kimia dari *Polyamida* (PA) atau *amida* penyusun polimer jenis nylon. Jenis nylon biasanya digunakan sebagai bahan dasar pembuatan senar pancing, jaring ikan dan serat pakaian (22). Puncak serapan 1424,89 cm^{-1} (stasiun 1 sedimen), 1423,82 cm^{-1} (stasiun 2 sedimen), 1423,59 cm^{-1} (stasiun 3 sedimen), 1464,73 cm^{-1} (stasiun 4 sedimen), 1435,06 cm^{-1} (stasiun 1 biota), 1403,90 cm^{-1} (stasiun 2 biota), 1405,77 cm^{-1} (stasiun 3 biota), dan 1415,45 cm^{-1} (stasiun 4 biota). Nilai serapan ini menunjukkan ikatan kimia CH_2 bend yang merupakan gugus fungsi dari polimer *Ethylene Vinyl Acetate* (EVA), *Acrylonitrile butadiene styrene* (ABS), dan *Polyvinyl chloride* (PVC) (22).

B. Bioaktivitas Pada Makrobentos

Aktivitas antioksidan *N. balteata* dan *C. aurisfelis* dapat ditinjau dari perubahan warna pada sampel yang diuji. Penelitian ini menggunakan metode DPPH dalam uji aktivitas antioksidan. Menurut (23), metode DPPH banyak digunakan dengan alasan karena sederhana, efisiensi waktu, hanya memerlukan sedikit sampel, peka, murah dan cepat. Perubahan warna larutan ekstrak *N. balteata* dan *C. aurisfelis* serta asam askorbat dapat dilihat pada Gambar 14.



(A) (B)

Gambar 14. Aktivitas Antioksidan Secara Kualitatif

Berdasarkan Gambar 14. (A: ekstrak *N. balteata*) diatas menunjukkan bahwa seri konsentrasi 1000 ppm dan 500 ppm terjadi perubahan menjadi warna kuning dari yang berwarna ungu, dimana hal ini dapat dikatakan bahwa kedua seri konsentrasi tersebut meredam radikal bebas. Pada Gambar 14, (A) seri konsentrasi 250 ppm, 125 ppm dan 62,5 ppm peredamannya masih relatif sedikit untuk mampu menghambat radikal bebas yang ditandai dengan sedikit perubahan warna ungu pekat menjadi warna ungu muda.

Beda halnya pada Gambar 14 (B : ekstrak *C. aurisfelis*) ketika asam askorbat dijadikan sebagai kontrol positif, dimana vitamin C murni mampu meredam radikal bebas sehingga ditandai dengan terjadinya perubahan kelima seri konsentrasi yang berwarna ungu menjadi warna kuning bening. Hal tersebut seperti yang disampaikan oleh (24) bahwa hasil warna kuning merupakan ciri spesifik dari reaksi radikal DPPH, dimana ketika antioksidan menyumbangkan elektron kepada DPPH. Metode DPPH berfungsi untuk mengukur elektron tunggal seperti aktivitas transfer hidrogen sekaligus untuk mengukur aktivitas penghambatan dari radikal bebas.

Kandungan antioksidan yang terdapat pada *N. balteata* dan *C. aurisfelis* perlu diketahui, hal ini berguna untuk memudahkan penelitian dimasa yang akan datang, terutama di bidang makanan dan pengobatan untuk perkembangan yang lebih baik lagi. Menurut (25), selain biasa dijadikan sebagai bahan makanan, gastopoda juga dapat dijadikan obat untuk mencegah berbagai penyakit.

Selain secara kualitatif, uji aktivitas antioksidan juga dapat ditinjau secara kualitatif dengan menggunakan nilai persentase inhibisi dan juga nilai IC_{50}. Pengukuran ini dilakukan dengan menggunakan spektrofotometer pada panjang gelombang 517 nm. Konsentrasi yang dibutuhkan oleh suatu sampel untuk menghambat 50% dari konsentrasi radikal DPPH yaitu nilai *Inhibitory Concentration$_{50}$*. Besarnya nilai IC_{50} pada ekstrak *N. balteata* dan *C. aurisfelis* dapat diketahui dari persamaan regresi linier menggunakan Microsoft Excel. Berdasarkan hasil perhitungan uji antioksidan dengan metode DPPH untuk ekstrak gastropoda *N. balteata* dan *C. aurisfelis* yang berasal dari Perairan Tanjung Api-Api maupun Taman Nasional Sembilang dan vitamin C murni sebagai pembanding dengan menggunakan pelarut etanol 96% dapat dilihat pada Tabel berikut ini.

Tabel 8. Hasil Uji Kuantitatif Kandungan Antioksidan Ekstrak *N. balteata*

Konsen. (ppm)	**NBTAA**			**NBTNS**			**Aktivitas Antioksidan**
	Abs	**%Inh**	**IC_{50}**	**Abs**	**%Inh**	**IC_{50}**	
1000	0,101	86,559		0,161	72,734		
500	0,134	78,802		0,189	66,283		
250	0,172	70,046	IC_{50} NBTAA 37,188 µg/mL	0,211	61,137	IC_{50} NBTNS 40,011 µg/mL	Sangat Kuat IC_{50}<50µg/mL
125	0,212	60,906		0,227	57,527		
62,5	0,226	57,680		0,243	53,840		

Absorbansi DPPH blanko 517 nm rata-rata = 0,476 NBTAA persamaan y = 10,914x + 10,535 R^2 = 0,9818

Absorbansi DPPH blanko 517 nm rata-rata = 0,476
NBTNS persamaan y = 6,7148x + 25,228
R^2 = 0,9827

Tabel 9. Hasil Uji Kuantitatif Kandungan Antioksidan Ekstrak *C. aurisfelis*

Konsen. (ppm)	**CATAA**			**CATNS**			**Aktivitas Antioksidan**
	Abs	**%Inh**	**IC_{50}**	**Abs**	**%Inh**	**IC_{50}**	
1000	0,125	80,952		0,140	77,496		
500	0,160	73,886		0,176	69,278		
250	0,192	65,591	IC_{50} 38,984 µg/mL	0,197	64,439	IC_{50} 33,301 µg/mL	Sangat Kuat IC_{50}<50µg/mL
125	0,216	59,985		0,218	59,524		
62,5	0,234	55,760		0,233	55,991		

Absorbansi DPPH blanko 517 nm rata-rata = 0,476
CATAA persamaan y = 9,2745x + 16,026
R^2 = 0,9855

Absorbansi DPPH blanko 517 nm rata-rata = 0,476
CATNS persamaan y = 7,6124x + 23,314
R^2 = 0,9827

Tabel 10. Hasil Uji Kuantitatif Kandungan Antioksidan Ekstrak *Scylla serrata*

Konsentrasi Sampel	Ekstrak *Scylla serrata*			Aktivitas Antioksidan
(ppm)	Absorbansi rata-rata	% Inhibisi	IC50	
300	0.065	93.536		Sangat Kuat
250	0.076	90.397	2.25 ppm	(IC50 < 10 ppm)
200	0.082	88.827		
150	0.087	87.535		
100	0.095	85.226		

Absorbansi DPPH blanko 517nm rata-rata = 0.403

Persamaan y = 6.9429x + 52.808

R^2 = 0.9327

Berdasarkan Tabel 8 dan Tabel 9 bahwa konsentrasi ekstrak yang digunakan untuk uji antioksidan yaitu 1000, 500, 250, 125 dan 62,5 ppm. Nilai IC_{50} pada ekstrak NBTAA diperoleh sebesar 37,188 µg/mL pada ekstrak NBTNS diperoleh 40,011 µg/mL. Selain itu nilai IC_{50} pada ekstrak CATAA diperoleh sebesar 38,984 µg/mL dan pada ekstrak CATNS diperoleh sebesar 33,301 µg/mL. Maka keempat ekstrak *N. balteata* dan *C. aurisfelis* baik dari Perairan Tanjung Api-Api maupun Taman Nasional Sembilang aktivitas antioksidannya masuk dalam kategori sangat kuat. Sama halnya dengan asam askorbat diperoleh nilai IC_{50} sebesar 22,821 µg/mL sebagai kontrol positif dan dikategorikan sangat kuat sesuai dengan ketentuan dari penelitian (26) bahwa IC_{50}<50 µg/mL dikategorikan antioksidan yang sangat kuat dapat dilihat pada Tabel 11. berikut.

Dari analisis aktivitas antioksidan secara kuantitatif, pada ekstrak etanol *S. serrata* didapat hasil IC50 yang cukup kuat yaitu sebesar 2.25 ppm. Antioksidan ini lebih kuat jika dibandingkan dengan penelitian (27) pada biota kerang Ale-Ale (*Metetrix* Sp.) yang didapat nilai IC50 sebesar 84.46 ppm yang tergolong ke dalam antioksidan sedang. Penelitian lainnya pada biota teripang *Holothuria atra* oleh didapat nilai IC50 sebesar 126 ppm dan tergolong ke dalam antioksidan lemah jika dibandingkan dengan nilai IC50 dari *Scylla serrata.*

Tabel 11. Hasil Peredaman Radikal DPPH Asam Askorbat

Konsen. (ppm)	**Asam Askorbat (Vit C)**			**Aktivitas Antioksidan**
	Abs	**%Inh**	**IC_{50}**	
1000	0,043	90,169	IC_{50} dari asam askorbat 22,821 µg/mL	Sangat Kuat IC_{50}<50µg/mL
500	0,064	85,330		
250	0,103	76,267		
125	0131	69,739		
62,5	0,174	59,908		
Absorbansi DPPH blanko 517 nm rata-rata = 0,476				
persamaan y = 10,981x + 15,652 R^2 = 0,9892				

Maka dapat dikatakan bahwa ekstrak *Nerita balteata* yang berasal dari Perairan Tanjung Api-Api dan *Cassidula aurisfelis* yang berasal dari Perairan Taman Nasional Sembilang memiliki aktivitas antioksidan yang lebih kuat karena memiliki nilai IC_{50} yang lebih kecil sebesar 37,188 µg/mL dan 33,301 µg/mL dibandingkan dengan ekstrak *Nerita balteata* yang berasal dari Perairan Taman Nasional Sembilang dan *Cassidula aurisfelis* yang berasal dari Perairan Tanjung Api-Api memiliki nilai IC_{50} sebesar 40,011 µg/mL dan 38,984 µg/mL.

Namun jika dibandingkan penelitian (28) sebelumnya tentang aktivitas antioksidan pada siput *Onchidium typhae* menghasilkan nilai IC_{50} sebesar 92,045 µg/mL, penelitian ini memiliki aktivitas antioksidan yang lebih kuat karena memiliki nilai IC_{50} yang lebih kecil. Hal ini sesuai dengan (29), bahwa nilai IC_{50} yang kecil maka aktivitas antioksidannya semakin tinggi. Persamaan regresi linier dari hubungan konsentrasi ekstrak dengan persen peredaman radikal akan menghasilkan nilai $IC_{50,}$

Hasil skrining fitokimia menunjukan bahwa ekstrak *N. balteata* dan *C. aurisfelis* keduanya mengandung senyawa golongan alkaloid, triterpenoid dan saponin. Kedua ekstrak ini tidak mendeteksi keberadaan senyawa flavonoid, steroid dan tanin. Penelitian lain dengan sampel *Onchidium typhae* ekstrak methanol juga mengandung senyawa alkaloid. Hal ini menunjukkan bahwa senyawa seperti alkaloid sering ditemukan di biota siput. Lebih jelasnya dapat dilihat pada Tabel 12.

Tabel 12. Hasil Skrining Fitokimia ekstrak etanol NBTAA dan CATNS

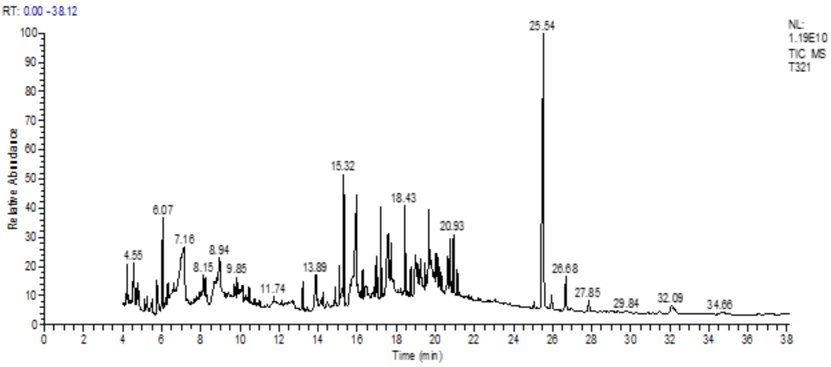
No.	**Parameter**	**Hasil Analisa**			**Metode**
		N. balteata	***C. aurisfelis***	***S. serrata***	
1.	Alkaloid	+	+	-	Analisa Kualitatif
2.	Flavonoid	-	-	+	
3.	Triterpenoid	+	+	+	
4.	Steroid	-	-	-	
5.	Saponin	+	+	-	
6.	Tanin	-	-	-	

Keterangan: (+) Positif mengandung senyawa metabolit sekunder
(-) Negatif mengandung senyawa metabolit sekunder

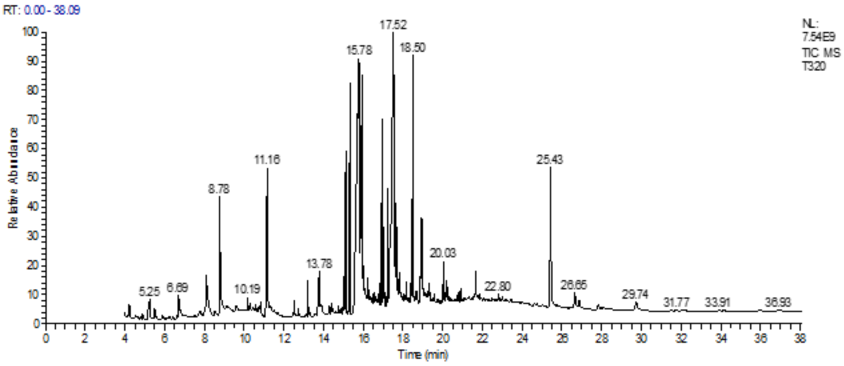
Hasil yang diperoleh dari uji fitokimia belum sepenuhnya akurat, terkadang disebabkan cukup kecilnya konsentrasi disuatu ekstrak sehingga senyawa bisa tidak terdeteksi, selain itu sifat uji fitokimia yang kualitatif. Alkaloid berguna sebagai antibakteri (30), sedangkan saponin memiliki kemampuan menurunkan kolestrol dalam darah dan menghambat sel tumor dan triterpenoid bermanfaat sebagai antivirus. Ekstrak etanol *Scylla serrata* mengandung komponen terpenoid, sesuai dengan analisis pada uji fitokimia. Adanya senyawa kimia terpenoid pada sampel ditandai dengan sampel yang menghasilkan cincin berwarna kecoklatan atau ungu. Senyawa yang terbuat dari Terpenoid memiliki sifat antibakteri, antiinflamasi dan penghambat sel kanker. Berdasarkan penelitian yang dilakukan oleh (31) pada biota laut jenis teripang laut, hasil uji fitokimia teridentifikasi positif kelompok senyawa antioksidan golongan flavonoid dan saponin melalui uji secara kualitatif pada sampel.

Beragam struktur dan fungsi terpenoid telah memicu peningkatan minat dalam penggunaan komersialnya. Berdasarkan penelitian yang dilakukan oleh (32), terpenoid juga memiliki sifat antibakteri, antijamur, antiparasit, antivirus, hipoalergenik, antispasmodik, antihiperglikemik, antiradang, dan imunomodulator, menjadikannya efektif dalam pencegahan dan pengobatan sejumlah penyakit, termasuk kanker. Terpenoid juga dapat dimanfaatkan untuk melindungi produk pertanian selama penyimpanan karena diketahui memiliki kualitas insektisida. Secara kualitatif terbukti senyawa flavonoid ada di dalam ekstrak etanol *S. serrata.* Terdapatnya senyawa flavonoid pada ekstrak etanol *S. serrata* ditandai dengan terbentuknya perubahan warna menjadi biru, ungu, hijau, merah maupun hitam. Flavonoid termasuk ke dalam senyawa fenolik sebagai senyawa antioksidan, antikanker, dan antimikroba. Berdasarkan penelitian yang dilakukan oleh (33) keunggulan molekul flavonoid juga dapat membantu vitamin C bekerja lebih baik, bertindak sebagai anti inflamasi, menghentikan keropos tulang, dan bertindak sebagai antibakteri.

GC-MS digunakan untuk menentukan profil senyawa bioaktif yang terdapat dalam ekstrak etanol NBTAA dan CATNS (Gambar 15). Hasil analisis senyawa GC-MS kemudian diurutkan berdasarkan titik puncak. Selain itu untuk mengelompokkan jenis senyawa yaitu memasukkan *running time*, area, *probability*, nama senyawa serta rumus senyawa menjadi informasi data penting untuk mengelompokkan jenis senyawanya (Tabel 13 dan 14).



(A)



(B)

Gambar 15. Grafik Analisis GCMS Ekstrak Etanol (A) NBTAA, (B) CATNS

Tabel 13. Hasil Analisis GC-MS Ekstrak Etanol NBTAA.

No.	R.Time	Probability	Area%	Name	Aktivitas Biologi	Rumus Kimia	Sumber
1	4,24	29,27	1,8	Cyclopentanemethanol, 1-amino-	Triterpenoid	C6H13NO	(Nogueira *et al.* 2020)
2	4,55	1077	2,5	1-Methyl-2-pyrrolidineethanol		C7H15NO	(Puri dan Winata, 2019)
3	5,52	31,85	1,3	1,3-Pentanediamine		C5-H14-N2	
4	5,75	64,76	2,15	Benzeneethanamine		C8H11N	
5	6,06	95,34	4,05	L-Homoserine lactone, N,N-dimethyl-		C6H11NO2	
6	7,1	39,09	7,21	2-Piperidinone	Alkaloid	C5H9NO	(Sirait *et al.* 2019)
7	7,16	50,77	2,64	2-Piperidinone	Alkaloid	C5H9NO	(Sirait *et al.* 2019)
8	8,14	10,59	1,25	3-O-Benzyl-d-glucose		C13H18O6	
9	8,24	18,88	1,21	Diisopropyl(ethoxy)silane		C8H20OSi	
10	8,7	57,62	2,84	dl-Citrulline	Asam amino	C6H13N3O3	(Allerton *et al.* 2018)
11	8,95	13,1	4,09	N-[4-Aminobutyl]aziridine		C6H14N2	
12	13,89	49,21	2,65	Tetradecanoic acid		C14H28O2	
13	15,32	70,38	3,08	Hexadecanoic acid, methyl ester	Asam lemak	C17H34O2	(Karunia *et al.* 2017)
14	15,78	33,63	2,13	9-Hexadecenoic acid	Asam lemak	C16H30O2	(Karunia *et al.* 2017)
15	15,96	65,18	8,13	n-Hexadecanoic acid	Asam lemak	C16H32O2	(Karunia *et al.* 2017))
16	16,45	36,85	1,31	Dasycarpidan-1-methanol, acetate (ester)	Alkaloid	C20H26N2O2	
17	16,99	10,72	1,33	10-Octadecenoic acid, methyl ester		C19H36O2	
18	17,22	29,89	1,86	Methyl stearate		C19H38O2	
19	17,58	19,06	5,49	trans-13-Octadecenoic acid	Asam lemak	C18H34O2	(Karunia *et al.* 2017)
20	17,74	36,31	3,42	Octadecanoic acid	Asam lemak	C27H56O8	(Karunia *et al.* 2017)
21	18,43	13,91	1,87	5,8,11,14-Eicosatetraenoic acid, methyl ester, (all-Z)-	Asam lemak	C21H34O2	(Karunia *et al.* 2017)
22	18,97	15,49	3,08	cis-5,8,11,14,17-Eicosapentaenoic acid	Asam lemak	C20H30O2	(Karunia *et al.* 2017)
23	1927	10,62	1,95	Octadecanoic acid, 3-hydroxy-, methyl ester	Asam lemak	C9H18O3	(Karunia *et al.* 2017)
24	19,68	17,86	3.7	Ethanol, 2-(octadecyloxy)-		C20H42O2	
25	19,8	7,89	1,29	Geranyl isovalerate	Triterpenoid	C15H26O2	(Rahmawati *et al.* 2017)
26	20,65	8,75	1,65	Ethanol, 2-(9-octadecenyloxy)-, (Z)-		C20H40O2	
27	20,76	18,13	1,97	Octadecanoic acid, 3-hydroxy-, methyl ester	Asam lemak	C9H18O3	(Karunia *et al.* 2017)
28	20,93	20,27	2,02	Octadecanoic acid, 3-hydroxy-, methyl ester	Asam lemak	C9H18O3	(Karunia *et al.* 2017)
29	25,53	46,68	19,97	Cholesterol	Steroid	C27H46O	(Athoriq, 2021)
30	26,68	64,25	2,06	Campesterol	Steroid	C28H48O	(Jati *et al.* 2019)

Tabel 14. Hasil analisis GC-MS Ekstrak Etanol CATNS

No.	R.Time	Probability	Area%	Nama Senyawa	Aktivitas Biologi	Rumus Kimia	Sumber
1	5.24	59.54	1.22	2,2-Dimethyl-3-heptanone		C9H18O	
2	6.69	37.51	1.42	Hexanoic acid, 1-cyclopentylethyl ester		C13H26O2	
3	8.1	11.09	2.15	7-Methylene-9-oxa-bicyclo[3.3.1]non2-ene		C9H12O	
4	8.78	51.81	3.88	3-Decanol		C10H22O	
5	11.15	10.32	4.83	Methane, [(1 ethynylcyclohexyl)oxy]methoxy		C10H16O2	
6	13.78	75.45	2.8	Tetradecanoic acid		C14H28O2	
7	15	18.58	0.78	Methyl 6,9,12-hexadecatrienoate		C17H28O2	
8	15.12	41.53	4.09	9-Hexadecenoic acid, methyl ester, (Z)	Asam lemak	C17H32O2	(Karunia dan Sumarni, 2017)
9	15.32	83.89	6.05	Hexadecanoic acid, methyl ester	Asam lemak	C17H34O2	(Karunia dan Sumarni, 2017)
10	15.78	35.77	15.6	cis-9-Hexadecenoic acid	Asam lemak	C16H30O2	(Karunia dan Sumarni, 2017)
11	15.94	63.28	9.79	n-Hexadecanoic acid	Asam lemak	C16H32O2	(Karunia dan Sumarni, 2017)
12	16.94	89.68	3.91	Hexadecanoic acid, 3,7,11,15-tetramethyl-, methyl ester	Asam lemak	C21H42O2	(Karunia dan Sumarni, 2017)
13	17	9.65	2.1	trans-13-Octadecenoic acid, methyl ester	Asam lemak	C19H36O	(Karunia dan Sumarni, 2017)
14	17.22	35.6	2.24	Methyl stearate		C19H38O2	
15	17.35	24.16	0.93	cis-Vaccenic acid		C18H34O2	
16	17.52	24.4	15.49	trans-13-Octadecenoic acid	Asam lemak	C18H34O	(Karunia dan Sumarni, 2017)
17	17.66	64.89	1.76	Octadecanoic acid	Asam lemak	C27H56O8	(Karunia dan Sumarni, 2017)
18	17.81	10.12	0.77	[1,1'-Bicyclopropyl]-2-octanoic acid, 2'-hexyl-, methyl ester		C21H38O2	
19	18.43	30.37	2.22	5,8,11,14-Eicosatetraenoic acid, methyl ester, (all-Z)-		C21H34O	
20	18.5	39.36	4.96	5,8,11,14,17-Eicosapentaenoic acid, methyl ester, (all-Z)-		C21H32O	
21	18.94	43.69	4.12	cis-5,8,11,14,17-Eicosapentaenoic acid		C20H30O	
22	20.03	20.67	0.86	cis-5,8,11,14,17-Eicosapentaenoic acid		C20H30O	
23	21.66	9.13	0.81	2,3-Dihydroxypropyl elaidate		C21H40O4	
24	25.43	44.35	6.38	Cholesterol	Steroid	C27H46O	(Athoriq, 2021)
25	26.65	55	0.82	Ethyl iso-allocholate	Steroid	C26H44O5	(Simanjuntak *et al*. 2021)

Berdasarkan Tabel 10 dan Tabel 11 diatas, senyawa dengan persentase luas area terbesar pada kode sampel NBTAA yaitu *Cholesterol* merupakan senyawa golongan alkaloid dengan retensi waktu 25,53 menit serta luas area 19,97% dan persentase luas area terkecilnya yaitu *Diisopropyl(ethoxy)silane* dengan retensi waktu 8,24 menit serta luas area 1,21%. Pada kode sampel CATNS jenis senyawa dengan persentase luas area terbesar yaitu *cis-9-Hexadecenoic acid* yang merupakan golongan senyawa asam lemak dengan retensi waktu 15,78 menit serta luas area 15,6%, dan persentase luas area terkecilnya yaitu *[1,1'-Bicyclopropyl]-2-octanoic acid, 2'-hexyl-, methyl ester* dengan retensi waktu 17,81 menit serta luas area 0,77%.

D. **STATUS LUARAN**: Tuliskan jenis, identitas dan status ketercapaian setiap luaran wajib dan luaran tambahan (jika ada) yang dijanjikan. Jenis luaran dapat berupa publikasi, perolehan kekayaan intelektual, hasil pengujian atau luaran lainnya yang telah dijanjikan pada proposal. Uraian status luaran harus didukung dengan bukti kemajuan ketercapaian luaran sesuai dengan luaran yang dijanjikan. Lengkapi isian jenis luaran yang dijanjikan serta mengunggah bukti dokumen ketercapaian luaran wajib dan luaran tambahan melalui BIMA.

Luaran Tahun 2023 (Tahun kedua):

A. Luaran Wajib

1. Jenis : Artikel Jurnal Internasional Bereputasi (Q2)
   Identitas : Science and Technology Indonesia (ISSN: 2580-4391) – Scopus Q2
   Status : Publish
2. Jenis : Buku Referensi
   Identitas : Penerbit Amerta Media (ISSN: 9786234192926)
   Status : Draft

B. Luaran Tambahan

1. Jenis : Artikel Jurnal Internasional Bereputasi (Q4)
   Identitas : Malaysian Journal of Analytical Sciences (ISSN: 1394-2506) – Scopus Q4
   Status : Submit
2. Jenis : Artikel pada Konferensi Internasional
   Identitas : The 6th EMBRIO International Symposium (EIS)
   Status : Submit

E**. PERAN MITRA:** Tuliskan realisasi kerjasama dan kontribusi Mitra baik *in-kind* maupun *in-cash* (untuk Penelitian Terapan, Penelitian Pengembangan, PTUPT, PPUPT serta KRUPT). Bukti pendukung realisasi kerjasama dan realisasi kontribusi mitra dilaporkan sesuai dengan kondisi yang sebenarnya. Bukti dokumen realisasi kerjasama dengan Mitra diunggah melalui BIMA.

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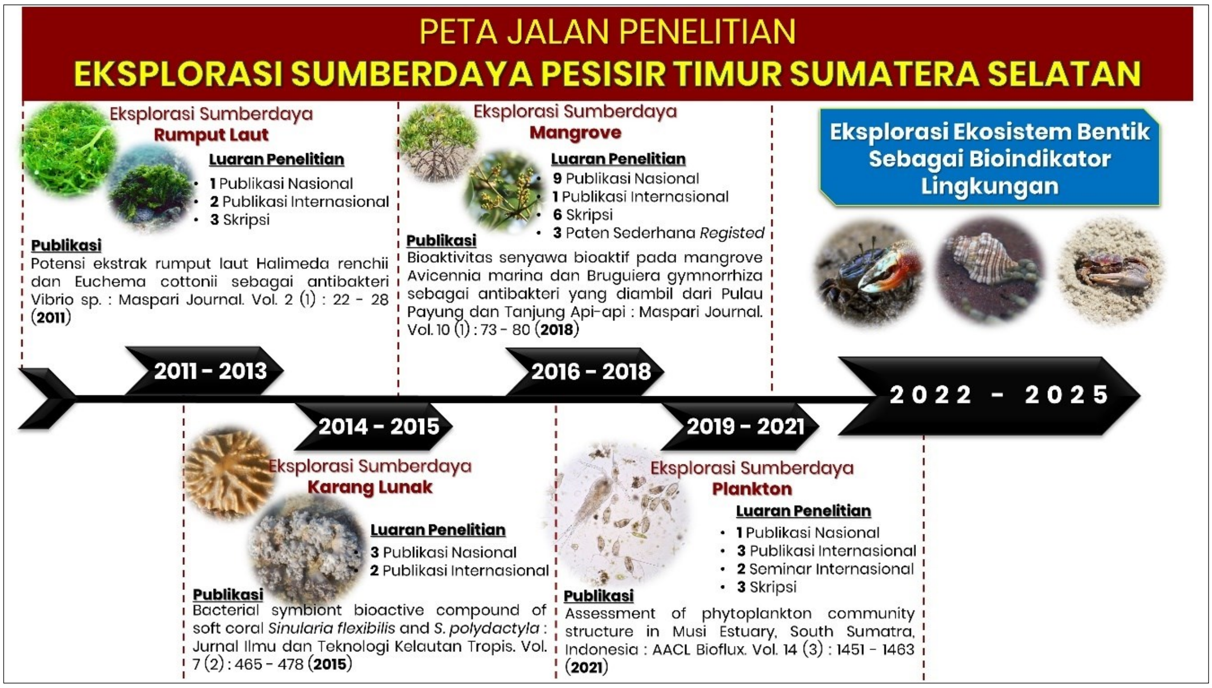
F. **KENDALA PELAKSANAAN PENELITIAN**: Tuliskan kesulitan atau hambatan yang dihadapi selama melakukan penelitian dan mencapai luaran yang dijanjikan, termasuk penjelasan jika pelaksanaan penelitian dan luaran penelitian tidak sesuai dengan yang direncanakan atau dijanjikan.

Penelitian ini melibatkan beberapa mahasiswa S1 dalam pengerjaannya sekaligus menjadi studi tugas akhir mereka. Keterlibatan secara langsung tersebut membutuhkan waktu yang cukup panjang secara administrasinya sehingga jalannya penelitian ini sedikit terlambat terutama pada topik identifikasi senyawa aktif biota pada ekosistem bentik. Namun seiring berjalannya waktu, keterlambatan jadwal tersebut tetap dikejar sesuai target perminggunya. Secara umum, pelaksanaan tiap tahap penelitian tidak memiliki hambatan yang signifikan, namun tim telah bekerja secara optimal sehingga target capaian telah terlaksana dengan baik.

G. **RENCANA TAHAPAN SELANJUTNYA:** Tuliskan dan uraikan rencana penelitian di tahun berikutnya berdasarkan indikator luaran yang telah dicapai, rencana realisasi luaran wajib yang dijanjikan dan tambahan (jika ada) di tahun berikutnya serta *roadmap* penelitian keseluruhan. Pada bagian ini diperbolehkan untuk melengkapi penjelasan dari setiap tahapan dalam metoda yang akan direncanakan termasuk jadwal berkaitan dengan strategi untuk mencapai luaran seperti yang telah dijanjikan dalam proposal. Jika diperlukan, penjelasan dapat juga dilengkapi dengan gambar, tabel, diagram, serta pustaka yang relevan. Pada bagian ini dapat dituliskan rencana penyelesaian target yang belum tercapai.

Semua data yang dikumpulkan akan dilakukan analisis sebagai bagian dari pengerjaan penelitian ini. Analisa terhadap data akan dilakukan oleh semua anggota tim untuk menemukan fenomena-fenomena terbaru yang mendukung kebaharuan ilmu pengetahuan sebagai salah satu unsur yang wajib ada dalam penulisan artikel ilmiah khususnya pada jurnal-jurnal internasional bereputasi yang menjadi target luaran wajib dan tambahan di tahun kedua.

Pengerjaan penelitian yang telah dilakukan akan menghasilkan data-data yang mendukung tujuan besar Peta Jalan Penelitian yaitu Eksplorasi Ekosistem Bentik sebagai Bioindikator Lingkungan. Selanjutnya, kajian tersebut akan bermanfaat pada pengembangan bidang *Marine Bioprospecting*. Hasil penelitian tersebut diharapkan akan diimplementasikan sebagai sebuah produk yang bermanfaat bagi sosial ekonomi masyarakat dan pengembangan produk kesehatan berbasis sumber daya alam dan pesisir. Sejalan dengan kegiatan penelitian yang terus berlanjut, artikel hasil penelitian akan terus dipublikasikan sebagai luaran wajib dan tambahan pada tahun yang sama dengan tahun kegiatan dan di tahun berikutnya.



Gambar 16. Peta jalan penelitian

Keanekaragaman hayati yang tersedia di kawasan pesisir Sumatera Selatan yang tinggi terutama pada komunitas bentik yang didukung oleh kondisi geografis yang memadainya untuk hidup. Berdasarkan data penelitian, kelas bentik gastropoda ditemukan dalam kelimpahan yang cukup tinggi di perairan Sumatera Selatan. Namun, faktor tekanan lingkungan yang cukup tinggi di kawasan ini dapat mengganggu kehidupan dan kelestariannya. Berdasarkan hal tersebut, kajian eksplorasi ekosistem bentik yang mempunyai nilai secara komersil dan lingkungan perlu dilakukan.

Tabel 15. Jadwal penelitian Tahun ke-2

No	Nama Kegiatan	Bulan											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Preparasi sampel												
2	Pengujian kuantitatif pencemaran pada biota bentos												
3	Maserasi dan ekstraksi												
4	Pengujian bioassay												
5	Pengujian kandungan fitokimia												
6	Analisis senyawa (GC-MS)												
7	Menulis draf artikel wajib dan tambahan												
8	Submit artikel ke jurnal internasional bereputasi												
9	Laporan akhir Tahun Kedua												

Keterangan warna : Hijau : Sudah terlaksana

Penelitian ini telah mencapai tahap akhir yaitu menyelesaikan luaran wajib dan tambahan berupa publikasi artikel dan penerbitan buku dari data yang telah dikumpulkan. Luaran wajib penelitian ini telah mempublikasikan satu artikel jurnal pada jurnal internasional terindeks Scopus Q2 (*Status Publish*). Namun, penyelesaian buku sebagai luaran wajib masih dalam penyelesaian draft naskah (*Status Drafting*). Sebagai luaran tambahan, penelitian ini telah men-submit 1 artikel pada jurnal internasional terindeks Scopus Q4 (*Status submit*) dan 1 artikel yang diseminasikan pada konferensi internasional yang kemudian akan dipublikasi pada prosiding jurnal E3S Web of Conferences (*Status Submit*).

H. DAFTAR PUSTAKA: Penyusunan Daftar Pustaka berdasarkan sistem nomor sesuai dengan urutan pengutipan. Hanya pustaka yang disitasi pada laporan akhir yang dicantumkan dalam Daftar Pustaka.

1. Almaniar S, Rozirwan, Herpandi. Abundance and diversity of macrobenthos at Tanjung Api-Api waters, South Sumatra, Indonesia. AACL Bioflux. 2021;14:1486–1497.
2. Li Q, Wang G, Wang H, Shrestha S, Xue B, Sun W, Yu J. Macrozoobenthos variations in shallow connected lakes under the influence of intense hydrologic pulse changes. J Hydrol. 2020;584:124755.
3. Sharifian S, Kamrani E, Saeedi H. Global biodiversity and biogeography of mangrove crabs: Temperature, the key driver of latitudinal gradients of species richness. J Therm Biol. 2020;92:102692.
4. Li X, Dong Y. Living on the upper intertidal mudflat: Different behavioral and physiological responses to high temperature between two sympatric cerithidea snails with divergent habitat-use strategies. Mar Environ Res. 2020;159:105015.
5. Mei K, Wu G, Liu J, jiajia Wu, Hong H, Lu H, Yan C. Dynamics of low-molecular-weight organic acids for the extraction and sequestration of arsenic species and heavy metals using mangrove sediments. Chemosphere. 2022;286(Pt 3).
6. Ahmad Z, Khan SM, Page SE, Balzter H, Ullah A, Ali S, Jehangir S, Ejaz U, Afza R, Razzaq A, Mukhamezhanova AS. Environmental sustainability and resilience in a polluted ecosystem via phytoremediation of heavy metals and plant physiological adaptations. J Clean Prod. 2023;385(October 2022):135733.
7. Monteiro IB, Dantas D V, Makrakis MC, Lorenzi L, Ribeiro SA, Pezzin APT, Silveira VF, Gentil E. Composition and spatial distribution of floating plastic debris along the estuarine ecocline of a subtropical coastal lagoon in the Western Atlantic. Mar Pollut Bull. 2022;179:113648.
8. Zhou Q, Tu C, Fu C, Li Y, Zhang H, Xiong K, Zhao X, Li L, Waniek JJ, Luo Y. Characteristics and distribution of microplastics in the coastal mangrove sediments of China. Sci Total Environ. 2020;703:134807.

9. Vasanthi RL, Arulvasu C, Kumar P, Srinivasan P. Ingestion of microplastics and its potential for causing structural alterations and oxidative stress in Indian green mussel Perna viridis– A multiple biomarker approach. Chemosphere. 2021;283:130979.

10. Bruno C, Blasi MF, Mattei D, Martellone L, Brancaleone E, Savoca S, Favero G. Polymer composition analysis of plastic debris ingested by loggerhead turtles (Caretta caretta) in Southern Tyrrhenian Sea through ATR-FTIR spectroscopy. Mar Environ Res. 2022;179:105676.

11. Akindele EO, Ehlers SM, Koop JHE. First empirical study of freshwater microplastics in West Africa using gastropods from Nigeria as bioindicators. Limnologica. 2019;78:125708.

12. Zhang L, Liu J, Xie Y, Zhong S, Gao P. Occurrence and removal of microplastics from wastewater treatment plants in a typical tourist city in China. J Clean Prod. 2021;291:125968.

13. Kousoulaki K, Grøtan E, Kortner TM, Berge GM, Haustveit G, Krogdahl, Nygaard H, Sæle, Chikwati EM, Lein I. Technical feed quality influences health, digestion patterns, body mineralization and bone development in farming of the stomachless cleaner fish ballan wrasse (Labrus bergylta). Anim Feed Sci Technol. 2021;274:114830.

14. Yani IN, Siregar YI, Amin B. Analysis of Types and Abundance of Micropllastic in Water and Sediment in Coastal Waters of Pandan District, Central Tapanuli Regency, North Sumatra. Asian J Aquat Sci. 2021;4(3):215–220.

15. Nugroho RY, Rozirwan, Fauziyah. Karakteristik Mikroplastik Pada Saluran Pencernaan Kerang Anadara granosa (Linnaeus, 1758) Menggunakan Metode Ekstraksi Basa. SIMBIOSA. 2023;12(1):1–11.

16. Al Nahian S, Rakib MRJ, Haider SMB, Kumar R, Mohsen M, Sharma P, Khandaker MU. Occurrence, spatial distribution, and risk assessment of microplastics in surface water and sediments of Saint Martin Island in the Bay of Bengal. Mar Pollut Bull. 2022;179:113720.

17. Pitacco V, Orlando-Bonaca M, Avio CG. 4 - Plastic impact on marine benthic organisms and food webs [Internet]. In Bonanno G, Orlando-Bonaca MBT-PP and MC, editors. . Academic Press; p.95–151.

18. Joshy A, Krupesha Sharma SR, Mini KG. Microplastic contamination in commercially important bivalves from the southwest coast of India. Environ Pollut. 2022;305:119250.

19. Coates J. Interpretation of infrared spectra, a practical approach. 2000;

20. Gawad SSA. Concentrations of heavy metals in water, sediment and mollusk gastropod, Lanistes carinatus from Lake Manzala, Egypt. Egypt J Aquat Res. 2018;44(2):77–82.

21. Costa JPD, Duarte AC, Rocha-Santos TAP. Chapter.-1, microplastics occurrence, fate and behaviour in the environment. Compr Anal Chem. 2017;75.

22. Jung MR, Horgen FD, Orski S V, Rodriguez V, Beers KL, Balazs GH, Jones TT, Work TM, Brignac KC, Royer S-J. Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms. Mar Pollut Bull. 2018;127:704–716.

23. Molyneux P. The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. Songklanakarin J Sci Technol. 2004;26(2):211–219.

24. Sopalun K, Laosripaiboon W, Wachirachaikarn A, Iamtham S. Biological potential and chemical composition of bioactive compounds from endophytic fungi associated with thai mangrove plants. South African J Bot. 2021;141:66–76.

25. Pachaiyappan A, Muthuvel A, Sadhasivam G, Sankar VJV, Sridhar N, Kumar M. In vitro antioxidant activity of different gastropods, bivalves and echinoderm by solvent extraction method. Int J Pharm Sci Res. 2014;5(6):2539–2545.

26. Supriatna D, Mulyani Y, Rostini I, Agung MUK. Aktivitas antioksidan, kadar total flavonoid dan fenol ekstrak metanol kulit batang mangrove berdasarkan stadia pertumbuhannya. J Perikan Kelaut. 2019;10(2):35–42.

27. Kalija TA, Warsidah W, Prayitno DI. Komponen Bioaktif dan Aktivitas Antioksidan Ekstrak Kerang Ale-Ale (Meretrix Sp.) Terfermentas. J Laut Khatulistiwa. 2020;3(1):10–13.

28. Kemuning GI, Wijianto B, Fahrurroji A. Uji Antioksidan Ekstrak Metanol Siput Onchidiid (Onchidium typhae) dengan Metode DPPH. J Ilmu Kedokt dan Kesehat Indones. 2022;2(3):130–139.

29. Mazliena AWS, Ahmad Tarmizi Wan Yusop S, Hafizi Sukairi A, Razip Asaruddin M. Phytochemical

Screening, Determination of Antioxidant Activity and Alpha-Amylase Inhibitory Activity of Nypa fruticans Sugar. Mater Today Proc. 2019;19:1745–1751.

30. Prasathkumar M, Raja K, Vasanth K, Khusro A, Sadhasivam S, Sahibzada MUK, Gawwad MRA, Al Farraj DA, Elshikh MS. Phytochemical screening and in vitro antibacterial, antioxidant, anti-inflammatory, anti-diabetic, and wound healing attributes of Senna auriculata (L.) Roxb. leaves. Arab J Chem. 2021;14(9):103345.

31. Akerina FO, Sangaji J. Analisis Fitokimia dan Toksisitas serta Aktivitas Antioksidan Beberapa Jenis Teripang di Desa Kakara, Halmahera Utara. J Agribisnis Perikan. 2019;12(2):188–196.

32. Sampulawa S, Bahalwan F. Identifikasi Senyawa Bioaktif Ekstrak Alga Coklat (Hormophysa triquetra). J Ilm Biol. 2022;10(1):212–217.

33. Nurmila N, Sinay H, Watuguly T. Identifikasi dan analisis kadar flavonoid ekstrak getah angsana (Pterocarpus indicus Willd) di dusun Wanath kecamatan Leihitu kabupaten Maluku Tengah. J Biol Pendidik dan Terap. 2019;5(2):65–71.

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Research Paper

An Assessment of Pb and Cu in Waters, Sediments, and Mud Crabs (*Scylla serrata*) from Mangrove Ecosystem Near Tanjung Api-Api Port Area, South Sumatra, Indonesia

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Abstract
Heavy metal pollution from anthropogenic activities can harm aquatic ecosystems. This study aims to determine the concentration of heavy metals (Pb and Cu) in waters, sediments, and mud crabs (*Scylla serrata*), and to analyze the relationship between environmental parameters and *S. serrata* which is consumed by humans. Samples were taken in the mangrove ecosystem around the Tanjung Api-Api port area in South Sumatra, Indonesia. Pb and Cu analysis used the Atomic Absorption Spectrophotometer (AAS). Pb and Cu linkages in waters, sediments, and *S. serrata* analyzed by SigmaPlot V12.5 and Principal Component Analysis (PCA) analyzed by XLSTAT 2022. The limit consumption of *S. serrata* was calculated using MWI (Maximum Weekly Intake) and MIT (Maximum Intake Tolerance). Based on the results, the heavy metal Pb in water was 0.1055 – 0.1322 mg.L^{-1}, and Cu was not detected. Furthermore, Pb in sediments ranged from 7.0104 - 11.8186 mg.kg^{-1}, Cu 3.7127 - 4.5347 mg.kg^{-1}, and Pb in *S. serrata* ranged from 0.0001 - 0.0021 mg.kg^{-1}, and Cu ranged from 0.03 – 0.0791 mg.kg^{-1}. The concentration of heavy metals in water, sediment, and *S. serrata* had not exceeded the specified quality standard, except for Pb in water. The principal component analysis obtained F1 (44.35%), F2 (27.53%) and F3 (17.83%) groups. Based on MWI and MIT values that *S. serrata* was still safe for human consumption.

Keywords
Anthropogenic Activities, Heavy Metals, Mud Crab, Sediment

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1. INTRODUCTION

The rapid economic development in coastal areas, such as industrial activities, household waste, agriculture, and port activities, produces substantial quantities of pollutants discharged into coastal waters (Apri et al., 2021; Rizk et al., 2022). The waste generated from these activities can cause a decrease in water quality, impacting aquatic ecosystems (Rozirwan et al., 2022). One of the causes of the decline in water quality is heavy metal pollution because it has toxic, persistent, and bioaccumulate characteristics in nature, which can have detrimental effects on global ecosystems and human health (Briffa et al., 2020; Rizk et al., 2022). Heavy metals belong to the group of pollutants because they are difficult to decompose (non-degradable) and are easy to accumulate with a weight of 5 g.cm^{-3} (Shrestha et al., 2021).

In general, heavy metals for the growth and development of organisms are divided into two categories: essential and non-essential heavy metals. Many essential heavy metals such as Cu, Fe, Mn, Co, Zn, and Ni are essential for maintaining the human body metabolism as long as they are not used excessively. Non-essential heavy metals such as Cd, Pb, Hg, Cu, and Al are not even needed in small amounts for every metabolic process and can cause poisoning (toxicity) (Bharti and Sharma, 2022). These metals pollute the waters and accumulate in sediments and organisms (Rizk et al., 2022). The high level of heavy metals in the waters negatively influences the biochemical and morphological traits of microbes, organisms, and the human body, causing many serious diseases such as cancer, paralysis, and carcinogens. Human well-being can be threatened due to heavy metals, which are considered the main components of pollutants in environmental waters (Briffa et al., 2020).

Organisms from the crustacean class can be used as bioindicators of heavy metal contamination in waters and sediments because of their ability to accumulate heavy metals. *S. serrata* lives in muddy substrates, so it has the potential as a bioindicator of heavy metal pollution (Soegianto et al., 2022). *S. serrata* is one of the highest export commodities in Indonesia and is among the most prominent fishery products in Banyuasin

Regency, South Sumatra. Monitoring heavy metals in water, sediment, and *S. serrata* is important to determine the potential for bioaccumulation and for environmental management. The interaction between biotic and abiotic in the waters creates an interconnected atmosphere (Maxwell et al., 2017). All anthropogenic that occurs in the environment seems to be a marker to know the status of the biotic group (Huggett, 2018; Upadhyay, 2020). Waters have a very dynamic and actual character so regular monitoring is needed to determine the latest environmental quality (Whitehead et al., 2019; Ustaoğlu et al., 2020).

Several researchers have studied heavy metal content, including Cu, Zn, Mg, Cd, and Cr, in crabs from mangrove ecosystems in Qi'ao, China (Zhang et al., 2019). The accumulation of heavy metal Cd in *S. serrata* in estuarine (Zhang et al., 2022b), and heavy metal health risk assessment in *S. serrata*, East Java Indonesia (Soegianto et al., 2022). Tanjung Api-Api mangrove areas have an essential role for the people of South Sumatra, such as shipping routes leading to the port and fishery activities. The difference in this study is not only analyzing *S. serrata* but also the relationship between heavy metals in the water and sediments where *S. serrata* is captured. This study aimed to analyze the heavy metal content of Pb and Cu in water, sediment, and *S. serrata* with water parameters and the maximum limit of *S. serrata* consumption.

2. EXPERIMENTAL SECTION

2.1 Study Area and Sampling Location

This research was carried out in the mangrove ecosystem near the Tanjung Api-Api port area in South Sumatra, Indonesia, at five observation stations with extensive mangrove vegetation (Figure 1). This location received seawater from the Bangka strait and freshwater from the Banyuasin river (Saputra et al., 2021; Almaniar and Rozirwan, 2021; Nugroho et al., 2022). Anthropogenic activities such as port, agriculture, industry, fisheries, and households could impact on these quality waters. Apri et al. (2021) stated that anthropogenic sources affect water environmental quality. Samples were taken during low tide conditions. The water conditions at the time were ideal for various crustaceans and gastropods, which dug and moved to terrestrial substrates in mangroves for protection (Rozirwan et al., 2022).

Water samples were taken on the surface of the water using a 500 mL polyethylene bottle and then preserved using HNO_3 until the pH reached ≤ 2 to prevent changes in organic matter by bacterial activity and transferred in an ice box (Rizk et al., 2022). Sediment samples were taken using sediment core, then put in plastic bags and chilled in an ice box (Apri et al., 2021). Crab samples were taken using traps carried out at low tide. All samples obtained were taken to the laboratory for further analysis.

2.2 Environmental Parameters

Water quality measurements were carried out in situ with three repetitions consisting of salinity using a refractometer, water temperature using thermometer, dissolved oxygen (DO) using DO meter (Hanna HI 98193), and pH using pH meter (Hanna HI 9811–5) (Apri et al., 2021).

Figure 1. Map of Sampling Location in Mangrove Areas Near the Tanjung Api-Api Port

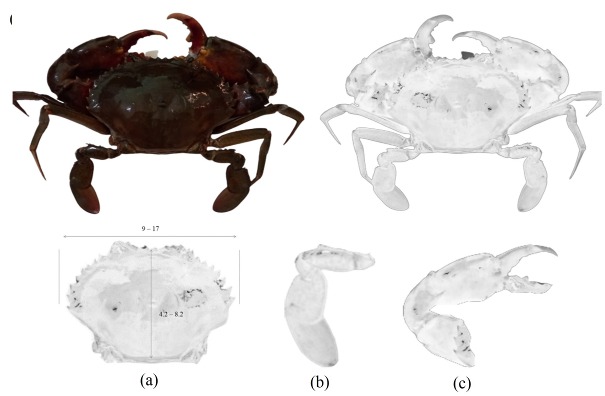

Figure 2. Details of *Scylla serrata* Morphological Characteristic; (a) Carapace, (b) Leg, (c) Cheliped

2.3 Sediment Grain Size Measurement

Sediment grain size analysis was carried out using wet sieving. Substrate type of sediment (gravel, sand, mud, and clay) analyzed using shepard triangle diagram with Microsoft Excel 2019. The type of sediment fraction was determined based on the most dominant values of the composition (Almaniar and Rozirwan, 2021).

2.4 Sample Preparation and Destruction

Water samples was filtered with 0.45 μm whatman filter paper, for sediment samples cleaned of foreign objects such as plastic pieces, and organic materials, to be further dried in an electric oven UF 55 Memmert at 60°C for 30 min and mashed into a powder with a mortar and pestle until fine particles and stored in polyethylene bottles (Yan et al., 2021). *S. serrata* was cleaned and mashed using a blender.

Destruction process were performed on heavy metals Pb and Cu for water, sediment, and *S. serrata* refers to (Rizk et al., 2022). Fifty milliliters of water sample was put into erlenmeyer and added 5 mL of HNO_3, heated with hotplate stirrer C-MAG HS 7 until the water sample reaches 15-20 mL. Furthermore, the sediment was acidly destroyed by putting ± 3 g of the sample in Erlenmeyer and adding 25 mL of distilled water to be heated on a hotplate with a temperature of 105°C-120°C. Mix HNO_3 as much as 5 mL and waited until the volume becomes 10 mL. After removal and cooling, added 5 mL of concentrated HNO_3 and 1 mL - 3 mL of $HClO_4$. The sediment sample was reheated with dampness until white smoke appeared, and the sample became clear, followed by heating for 30 min. After cooling, the sediment sample was filtered using quantitative filter paper.

Destruction of *S. serrata* samples was done using wet digestion to determined metal elements with low concentrations. The weighed sample was put into an Erlenmeyer, and HNO_3 (5–10 mL) and H_2O_2 (2 mL) were added. Digestion was carried out by setting up a microwave program. The result of the digestion was transferred into a 50 mL vial with ultra-distilled water and stored in polyethylene containers at room temperature until further measurements.

2.5 Atomic Absorption Spectroscopic Measurement

Measurement of heavy metal concentrations of Pb and Cu using an Atomic Absorption Spectrophotometer (Shimadzu AA-7000) with a wavelength of 283.3 nm for Pb and 324.7 nm for Cu.

2.6 Data Analysis

2.6.1 Bioconcentration Factor (BCF) Index

Bioconcentration factor (BCF) index were used to determine the pollutants bioaccumulation level in *S. serrata* mud crabs. The BCF calculated using the BCF formula.

$$\text{BCF index} = \frac{\text{Heavy metals concentration in biota}}{\text{Heavy metals concentration in water/sediment}} \qquad (1)$$

2.6.2 Distribution Levels of Heavy Metals

The distribution level of heavy metals Pb and Cu in water, sediment, and *S. serrata* was analyzed using SigmaPlot V12.5.

2.6.3 Principal Component Analysis (PCA)

Principal component analysis determined the relationship between water parameters (DO, temperature, pH, and salinity) and the concentration of heavy metals in water, sediment, and *S. serrata*. This analysis was processed using XLSTAT 2022 (Apri et al., 2021).

2.6.4 Maximum Limit of Heavy Metals Consumption

Provisional Tolerable Weekly Intake was weekly intake accepted (without health effects) of trace and toxic metals through marine biota samples. The determination of the maximum limit of heavy metal consumption contained in *S. serrata* could be calculated using the following formula.

$$\text{Maximum Weekly Intake} = \text{Weight} \times \text{Provosional Tolerable Weekly Intake} \qquad (2)$$

$$\text{Maximum Tolerable Intake} = \frac{\text{Maximum Weekly Intake}}{\text{Heavy metals concentration in biota}} \qquad (3)$$

3. RESULTS AND DISCUSSION

3.1 Environmental Parameters

The environmental parameters were measured in situ in the sampling station (Table 1). The ecological parameters measured at five stations were pH, dissolved oxygen, temperature, and salinity.

Based on the results of measurements, the pH values at all stations tended to close fresh water in the range of 6.09 to 7.02. The highest value was station 2, and the lowest was station 5. DO had varying values ranging from 4.7 to 7.18 $mg.L^{-1}$. The highest value was station 2, and the lowest was station one. Temperature and salinity at all stations were not much different, the temperature ranging from 23.57 to 25.54°C and salinity from 11 to 12 ‰.

The Tanjung Api-Api has an extensive mangrove area, which is suitable for biota as a place to feed ground and a habitat for their life cycle. The high anthropogenic activity in this location cause changes in environmental water quality. According to Almaniar and Rozirwan (2021), water quality parameters around Tanjung Api-Api waters were classified as moderate to heavily polluted. Water quality parameter changes can be caused by mixing water masses. Based on the results of environmental parameters, good conditions for the growth of *S. serrata* were found in all station based on dissolved oxygen, temperature, pH, and salinity. Mud crabs have good adaptation in different salinity conditions ranging from 10 ‰ to 34 ‰, pH 8.0 to 8.5, temperature 23°C to 30°C, and dissolved oxygen more than 3 $mg.^{-1}$ (Pedapoli and Ramudu, 2014). A significant increase in temperature will cause higher evaporation and impact the drying of the sludge substrate. This situation makes it difficult for mud crabs develop biologically such as mating and molting (Leoville et al., 2021). Moreover, very alkaline or acidic pH conditions will be dangerous because they can cause metabolic and respiratory disorders (Pedapoli and Ramudu, 2014; Paran et al., 2022). Salinity is an essential factor for the spread of organisms in the sea, and oxygen is a limiting factor in determining the presence of organisms in the water (Nugroho et al., 2023). The variety of dissolved oxygen can be affected by waste materials or pollutants in the water. Environmental factors can affect heavy metals variations in chemical and physical parameters tend to affect the presence, displacement, and toxicity (Soegianto et al., 2022).

Table 1. The Measurement of Environmental Parameters in the Sampling Station

Stations	pH	DO (mg.L^{-1})	Temperature (°C)	Salinity (‰)
1	6.76 ± 0.03	4.70 ± 0.17	25.29 ± 0.33	12 ± 0.00
2	7.02 ± 0.05	7.18 ± 0.07	23.57 ± 0.49	11 ± 0.00
3	6.45 ± 0.02	5.91 ± 0.12	24.33 ± 0.03	12 ± 0.00
4	6.47 ± 0.03	6.25 ± 0.22	24.33 ± 0.08	11 ± 0.00
5	6.09 ± 0.05	5.48 ± 0.03	25.54 ± 0.08	11 ± 0.00

Data are shown mean ± SD with 95% confidence level

3.2 Description of *Scylla serrata*

There were two crabs collected in each station. The crab had size at 66.91 – 404.91 g in weight, carapace width ranging from 9 cm to 17 cm, and carapace length ranging from 4.2 cm to 8.2 cm (Figure 2). Morphologically, *S. serrata* had a green carapace with nine spines on the right and left, six spines between the eyes, a red pincer tip larger on the right than the left, and three pairs of walking legs and a pair of swimming legs.

Many people eat mud crabs for seafood consumption. The selection of mud crabs as a measure of feasibility for consumption is also based on measuring the width of the carapace, divided into three phases. The juvenile phase has a carapace width of < 7 cm, the early stage has a carapace width of 7–12 cm, and the adult phase has a carapace width of >12 cm (Paran et al., 2022). Mud crabs have entered the adult phase, which is ready for consumption and has matured the gonads for reproduction. Mud crabs prepared to mate will enter mangrove forests. The environment of mangrove forests indicates a natural resource suitable for mud crabs. Nugroho et al. (2022) stated that the substrate on which mangrove vegetation develops is soft muddy, not hard soil.

3.3 Sediment Grain Size

The substrate type at the study site resulted from the Shephard Triangle Method (Figure 3). The determination of sedimentary substrates around the waters of Tanjung Api-Api mangrove areas were divided into four types (gravel, sand, mud, and clay). The results showed that the substrate type at all stations was clay. The sedimentary substrate around the Tanjung Api-Api mangrove areas was dominated by clay. The percentage of clay from all stations ranged from 83.04 to 91.79% (Table 2). The highest rate of clay was at station three, and the lowest was at station five. In other composition, sand percentage was from 3.04 to 8.37% and silt percentage was from 4.03 to 8.59%.

The sediment is the main accumulation point for metals in the aquatic environment. Heavy metal distribution in sediments is influenced by chemical sediment composition and grain size (Fitrah et al., 2020). *S. serrata* live in the area with clay substrate (Soegianto et al., 2022). Rozirwan et al. (2022) stated that mud crabs are often found in muddy substrates because suitable for their growth, provides a lot of food source and place to make holes to avoid predatory risk. Moreover, clay

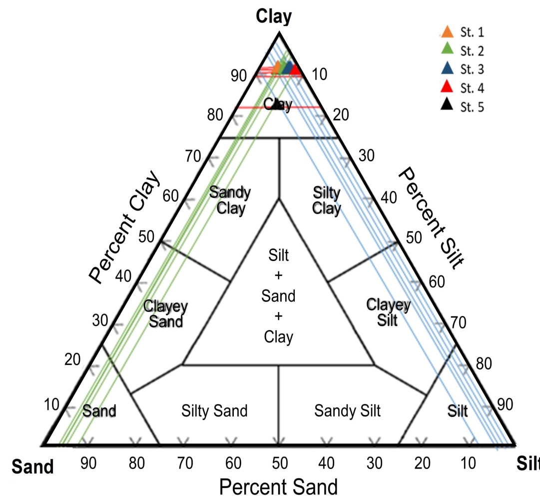

Figure 3. Classifications of Sediment Type with Shepard Triangle Method

Table 2. Sediment Grain Size in Each Station

Station	Sediment fraction (%)				Grain size
	Gravel	Sand	Mud	Clay	
1	0.00	6.74	4.89	88.36	Clay
2	0.00	5.56	4.03	90.41	Clay
3	0.00	3.04	5.17	91.79	Clay
4	0.00	4.30	4.31	91.39	Clay
5	0.00	8.37	8.59	83.04	Clay

substrate is easy to precipitate and accumulate because these particles have a high content of organic matter and high surface area for heavy metal absorption (Yan et al., 2021).

3.4 Heavy Metals Concentration

The results of heavy metal concentrations in water, sediments, and *S. serrata* were showed in (Table 3). Heavy metals in the water at all stations for Pb ranged from 0.1055 to 0.1334 mg.L^{-1}, and Cu was not detected (nd). Heavy metals in sediments for Pb ranged from 7.0104 to 11.8186 mg.kg^{-1}, and Cu ranged from 3.7127 to 4.5954 mg.kg^{-1}. Accumulation Pb in *S. serrata* ranged from nd at station 3 to 0.0021 mg.kg^{-1} at station 4 and

Cu ranged from 0.0300 to 0.0791 mg.kg^{-1}. The accumulation of heavy metal Pb in water had exceeded the quality standard value of 0.0044 mg.L^{-1} at all stations. Accumulation of Pb and Cu in sediments and *S. serrata* had not exceeded the quality standards. Based on the results of One-Way Anova analysis using a confidence level of 95% ($\alpha < 0.05$) showed significant difference in Pb concentration in sediment.

Aquatic ecosystems become ecosystems that are easily polluted by heavy metals because of mobility. Anthropogenic activities are one of the causes of water pollution (Zhang et al., 2022a). Heavy metal concentrations that have exceeded the quality standard allow for a decrease in water quality, sediments, and biota (Bharti and Sharma, 2022). Based on the analysis results, the concentration of Pb in the waters at each station has exceeded the threshold, and Cu was not detected. Avvari et al. (2022) stated that heavy metals in the water could disperse rapidly from their source because seawater is temporary and is affected by currents, tides, and other physical movements. Sampling in this study was carried out during low tide conditions. According to the conditions, the concentration of heavy metals tends to be higher because of the waters will experience a dilution process that will wash away the pollutants and affect their distribution (Rizk et al., 2022). Another activity factor that was estimated to have the potential to produce waste containing Pb was transportation and ports waste. Pb concentrations in waters are thought to have been influenced by ship maintenance activities and fuel oil spills from transportation activities (Briffa et al., 2020; Fitria et al., 2023).

3.5 Bioconcentration Factor (BCF) Indexs

Bioconcentration factors index (BCF) were used to determine the accumulation proportion of heavy metals Pb and Cu in *S. serrata* against heavy metals in sediment (Figure 4). Based on the results, the BCF value of heavy metals in *S. serrata* against in sediments ranged from 0 to 0.00024 (Pb) and 0.00690 to 0.01721 (Cu). The results showed that bioconcentration of Cu was higher than Pb in *S. serrata*. It could be concluded that the accumulation of Cu is higher than Pb in *S. serrata*.

The value of the BCF describes the ability of biota to accumulate heavy metals in the water and sediment in the environment (Bharti and Sharma, 2022; Rizk et al., 2022). The BCF of Cu is more incredible than Pb due to an essential metal organisms need in small amounts for metabolic processes. Still, if it exceeds the quality standards for heavy metals, it becomes toxic and harmful. High values of BCF indicate high levels of accumulated heavy metals and can have health implications that cannot be ignored for humans. According to Orabi and Khalifa (2020), a high BCF value in an organism indicates that the organism is capable of accumulating heavy metals. Bioaccumulation of heavy metals in organisms depends upon the concentration level in sediments, physiological factors, physicochemical properties, and biological activities in the ecosystem (Leoville et al., 2021; Bharti and Sharma, 2022).

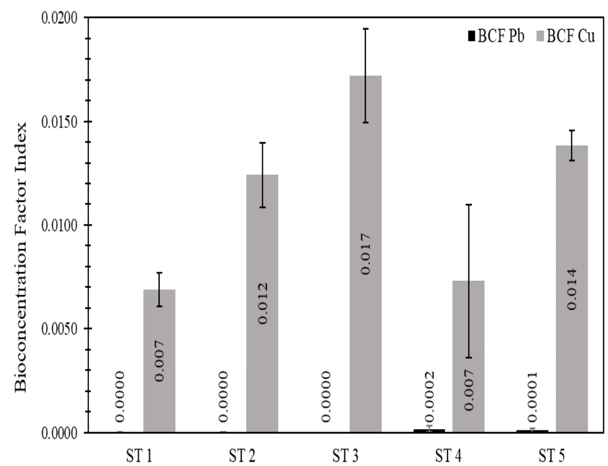

Figure 4. Bioconcentration factor (BCF) index of Pb and Cu in *S. serrata*

3.6 Distribution of Heavy Metals in Water, Sediment, and *Scylla serrata*

The distribution of Pb in waters, sediments, and *S. serrata* showed a parabolic line. In other media, Pb concentration showed fluctuation line in sediments and *S. serrata*. There was no distribution of Cu in the water because it was not detected at the time of measurement, whereas in sediment and *S. serrata* it formed a parabolic line distribution (Figure 5).

The distribution of Pb at the station 1 varied, sediment showed a high value, while water and *S. serrata* showed a low value compared to other stations. The heavy metal Pb at stations 2 to station 3 showed increasing pattern in sediments and waters, while decreasing in *S. serrata*. Furthermore, the distribution of Pb in water and sediment at station 4 had decreasing pattern, while at *S. serrata* it had an increasing pattern. At station 5, all accumulation media of Pb showed decreasing pattern. The distribution of Cu in sediments and *S. serrata* at station 1 showed a different pattern. Sediments showed the highest concentration compared to other stations, while *S. serrata* showed a low pattern. At station 2, the concentration of Cu in the sediment decreased, while at *S. serrata* it had an increasing pattern. The patterns between sediment and *S. serrata* was the same at stations 3, 4, and 5.

The concentrations of Pb and Cu in the sediments at all stations were still below the established quality standards, so it is still suitable for the habitat of *S. serrata*. Heavy metal concentrations in sediments are generally higher than in water (Bharti and Sharma, 2022). Heavy metals are also found to bind organic matter, settle to the bottom of the waters and blend with sediments (Algül and Beyhan, 2020; Rizk et al., 2022). Another factor, the research site is located in an estuary which forbidden place for waste containing heavy metals from anthropogenic activities (Niu et al., 2021; Zhang et al., 2022a). Moreover, the sedimentary substrate type influences the weight

Table 3. Pb and Cu Heavy Metals Accumulation in Water, Sediments, and *S. Serrata*

Sample	Heavy Metals	Quality Standard	Station				
			1	2	3	4	5
Water ($mg.L^{-1}$)	Pb	0.0044	0.1055	0.1322	0.1334	0.1309	0.1192
	Cu	0.0013	nd	nd	nd	nd	nd
Sediment ($mg.kg^{-1}$)	Pb	50	11.5922a	8.2391b	11.8186a	8.6954ab	7.0104c
	Cu	65	4.5347	4.2017	4.5954	3.7127	4.0055
S. serrata ($mg.kg^{-1}$)	Pb	1.5	0.0002	0.0001	nd	0.0021	0.0008
	Cu	10	0.0313	0.0550	0.0791	0.0300	0.0624

Note: nd: not detected

of accumulated metals (Yan et al., 2021). The finer substrate has a high surface area and a stable ionic density to bind heavy metal particles. According to the grain size of the sediment, the smaller one has higher potential heavy metals concentration.

Several studies of heavy metal accumulation in *S. serrata* and other commercial crab species have been reported in *S. serrata* species recovered from the waters off Threspuram, Southeast Coast of India, showed Pb concentrations of 0.72 $mg.kg^{-1}$ and Cu of 10.6 $mg.kg^{-1}$ in gills (Yogeshwaran et al., 2020). From the coast of East Java, Indonesia, several locations have been reported to have *S. serrata* with Pb and Cu accumulation including from Solo River with Pb of 0.395 $mg.kg^{-1}$ and Cu of 6.045 $mg.kg^{-1}$, Brantas River with Pb of 0.270 $mg.kg^{-1}$ and Cu of 5.627 $mg.kg^{-1}$, and Banyuwangi Coastal with Pb of 0.260 $mg.kg^{-1}$ and Cu of 5.142 $mg.kg^{-1}$ (Soegianto et al., 2022). Commercial crab species *Portunus trituberculatus* from the coastal waters of Zhejiang Province showed the accumulation of Pb of 0.077 $mg.kg^{-1}$ and Cu of 35.09 $mg.kg^{-1}$ (Liu et al., 2020). In northern Bay of Bengal, *Portunus pelagicus* species contained Pb of 1.67 $mg.kg^{-1}$ and Cu of 21.06 $mg.kg^{-1}$ (Karar et al., 2019).

The presence of heavy metals in the study site will also affect heavy metal accumulation in biota ecosystems. The concentrations of Pb and Cu in *S. serrata* meat were below the quality standard. Although the heavy metal contents were much more significant in the sediment, this value does not mean that the *S. serrata* value was safe. Another factor that causes heavy metal accumulation in *S. serrata* was a detritivor (Pedapoli and Ramudu, 2014; Paran et al., 2022). Crustaceans eat Polychaeta and zooplankton in the sediment, which means they absorb a lot of heavy metals (Fitrah et al., 2020). The higher concentration of Cu compared to Pb is because the body of the organism contains the heavy metal Cu, which functions in metabolic processes and the formation of hemoglobin, and because of its physiology when added to the body of an organism (Harlyan et al., 2015; Rizk et al., 2022). Cu derived from water can increase its concentration.*S. serrata* can regulate the levels of essential heavy metals in their bodies but cannot limit non-essential heavy metals (Leoville et al., 2021; Soegianto et al., 2022).

3.7 Principal Component Analysis (PCA)

The principal component analysis showed three groups of analysis (Figure 6). The cumulative percentage of F1, F2 and F3 were 44.35%, 27.53%, and 17.83%. The biplot of PCA was presented in 6. Based on the biplot, F1 observation was station 1, 2, and 4 while the variable was dissolved oxygen, Pb in waters, Cu and Pb in sediment, salinity, and temperature. F2 observation was station 3 while the variable was Cu and Pb in *S. serrata*. F3 observation was station 5 while the variable was pH.

The variations in Pb and Cu distribution patterns in waters, sediments, and *S. serrata* in this study could be caused by environmental conditions. According to Avvari et al. (2022) and Rizk et al. (2022), distribution of heavy metals can be affected by temperature, dissolved oxygen, pH, brightness, and salinity. Oceanographic factors can also cause differences in heavy metal levels caused by current velocities. Warmer water temperatures provide a higher potential for heavy metal solubility than normal temperature conditions (Selvi et al., 2019; Algül and Beyhan, 2020). The results also showed that the high Pb in the waters was inversely proportional to the low Cu in the sediments. Due to the characteristics of heavy metals, which are generally higher in sediments, it is possible that Pb will be higher in sediments (Bharti and Sharma, 2022; Rizk et al., 2022).

3.8 Maximum Consumption of *Scylla serrata*

The consumption limit of *S. serrata* could be calculated using the MWI (maximum weekly intake) and MTI (maximum tolerable intake) (Table 4). The maximum consumption limit of *S. serrata* (MTI) from the analysis was 2.343 kg per week (Pb) and 4.072 kg per week (Cu).

The limit of consumption of *S. serrata* allowed per week is very high because the concentration of Pb and Cu in *S. serrata* is lower than quality standard. Therefore, *S. serrata* is still very safe for consumption. However, this does not rule out the possibility that the path of heavy metal pollution can disrupt aquatic ecosystems and harm humans if not addressed immediately (Soegianto et al., 2022; Zhang et al., 2022b). Therefore, efforts are needed by the government and society to reduce heavy metal pollution so that aquatic ecosystems can be

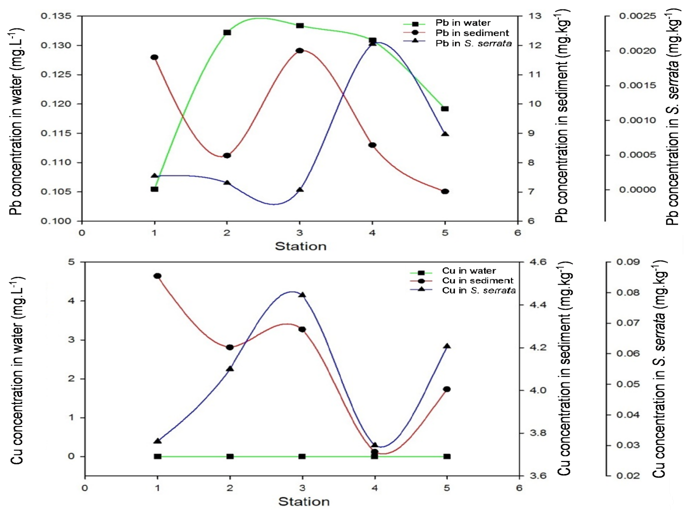

Figure 5. Distribution of Pb and Cu Heavy Metals in Each Station

Table 4. Maximum Consumption Limit of *S. serrata*

Heavy Metals	Average Concentration of Heavy Metals ($mg.kg^{-1}$)	PTWI ($mg.kg^{-1}$ per week)	Weight (kg)	MWI (mg per week)	MTI (kg per week)	Quality Standard (WHO, 1989) PTWI ($\mu g.kg^{-1}$ per week)	Quality Standard (WHO, 1989) PTWI ($mg.kg^{-1}$ per week)
Pb	0.00064	0.025	60	1.500	2.343	25	0.025
Cu	0.05156	3.500	60	210	4.072	3500	3.5

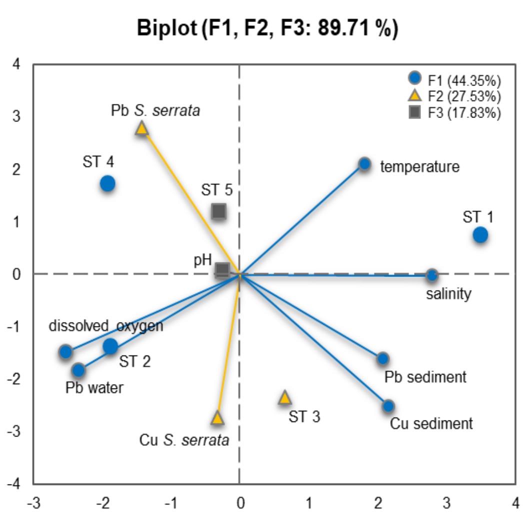

Figure 6. Principal Component Analysis of Environmental Parameters and Heavy Metals

sustainable (Briffa et al., 2020). Monitoring waste disposal into the waters regularly and inspecting ships to reduce oil spills into the seas are two forms of effort to control metal pollution. Outreach to the public about the survival of mud crabs and their relation to heavy metal waste in the waters is necessary to be safe for consumption.

4. CONCLUSION

The concentration of the heavy metal Pb in water has exceeded the quality standard while Pb and Cu concentrations in sediments and *S. serrata* has exceeded the quality standard. Based on the maximum limit value of meat consumption per week, *S. serrata* in Tanjung Api-Api is still safe for consumer. Future research should focus on analyzing heavy metals in another commercial marine biota.

5. ACKNOWLEDGEMENT

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REFERENCES

Algül, F. and M. Beyhan (2020). Concentrations and Sources of Heavy Metals in Shallow Sediments in Lake Bafa, Turkey. *Scientific Reports*, **10**(1); 11782

Almaniar, S. and H. Rozirwan (2021). Abundance and Diversity of Macrobenthos at Tanjung Api-Api Waters, South Sumatra, Indonesia. *AACL Bioflux*, **14**(3); 1486–1497

Apri, R., A. Agussalim, I. Iskandar, et al. (2021). Assessment the Macrobenthic Diversity and Community Structure in the Musi Estuary, South Sumatra, Indonesia. *Acta Ecologica Sinica*, **41**(4); 346–350

Avvari, L., C. K. Basuri, N. H. K. Chari, S. R. Tirukkovalluri, and N. R. Gollapalli (2022). Assessment of Heavy Metal Distribution in Seawater of Kakinada Bay, a Tropical Mangrove-Rich Coastal Environment. *Marine Pollution Bulletin*, **181**; 113877

Bharti, R. and R. Sharma (2022). Effect of Heavy Metals: An Overview. *Materials Today: Proceedings*, **51**; 880–885

Briffa, J., E. Sinagra, and R. Blundell (2020). Heavy Metal Pollution in the Environment and Their Toxicological Effects on Humans. *Heliyon*, **6**(9)

Fitrah, A., Ramses, F. Ismarti, Amelia, Rozirwan, and Suheryanto (2020). Diversity and Abundance of Polychaetes in the West Coast Waters of Batam Island, Kepulauan Riau Province-Indonesia. *AACL Bioflux*, **13**(1); 381–391

Fitria, Y., M. Fitrani, R. Y. Nugroho, and W. A. E. Putri (2023). Gastropods as Bioindicators of Heavy Metal Pollution in the Banyuasin Estuary Shrimp Pond Area, South Sumatra, Indonesia. *Acta Ecologica Sinica*; 1–9

Harlyan, L. I., D. Retnowati, S. H. J. Sari, and F. Iranawati (2015). Concentration of Heavy Metal (Pb and Cu) in Sediment and Mangrove Avicennia Marina at Porong River Estuary, Sidoarjo, East Java. *Research Journal of Life Science*, **2**(2); 124–132

Huggett, R. J. (2018). *Biomarkers: Biochemical, Physiological, and Histological Markers of Anthropogenic Stress*. CRC Press

Karar, S., S. Hazra, and S. Das (2019). Assessment of the Heavy Metal Accumulation in the Blue Swimmer Crab (*Portunus pelagicus*), Northern Bay of Bengal: Role of Salinity. *Marine Pollution Bulletin*, **143**; 101–108

Leoville, A., R. Lagarde, H. Grondin, L. Faivre, E. Rasoanirina, and N. Teichert (2021). Influence of Environmental Conditions on the Distribution of Burrows of the Mud Crab, *Scylla serrata*, in a Fringing Mangrove Ecosystem. *Regional Studies in Marine Science*, **43**; 101684

Liu, Q., Y. Liao, X. Xu, X. Shi, J. Zeng, Q. Chen, and L. Shou (2020). Heavy Metal Concentrations in Tissues of Marine Fish and Crab Collected from the Middle Coast of Zhejiang Province, China. *Environmental Monitoring and Assessment*, **192**; 1–12

Maxwell, P. S., J. S. Eklöf, M. M. van Katwijk, K. R. O'Brien, M. de la Torre-Castro, C. Boström, T. J. Bouma, D. Krause-Jensen, R. K. Unsworth, B. I. van Tussenbroek, et al. (2017). The Fundamental Role of Ecological Feedback Mechanisms for the Adaptive Management of Seagrass Ecosystems–A Review. *Biological Reviews*, **92**(3); 1521–1538

Niu, L., J. Li, X. Luo, T. Fu, O. Chen, and Q. Yang (2021). Identification of Heavy Metal Pollution in Estuarine Sediments under Long-Term Reclamation: Ecological Toxicity, Sources and Implications for Estuary Management. *Environmental Pollution*, **290**; 118126

Nugroho, R. Y., G. Diansyah, W. A. E. Putri, A. Agussalim, et al. (2023). Phytochemical Composition, Total Phenolic Content and Antioxidant Activity of *Anadara granosa* (linnaeus, 1758) Collected from the East Coast of South Sumatra, Indonesia. *Baghdad Science Journal*, **20**(4); 1258–1265

Nugroho, R. Y., M. Hendri, W. A. E. Putri, A. Agussalim, et al. (2022). Phytochemical Profile and Toxicity of Extracts from the Leaf of *Avicennia marina* (forssk.) Vierh. Collected in Mangrove Areas Affected by Port Activities. *South African Journal of Botany*, **150**; 903–919

Orabi, O. and M. M. Khalifa (2020). Biota Sediment Accumulation and Bioconcentration Factors of Trace Metals in the Snail *Melanoides tuberculata* Form the Agricultural Drains of the Manzala Lagoon, Egypt. *Environmental Science and Pollution Research*, **27**(15); 17754–17761

Paran, B. C., B. Jeyagobi, V. K. Kizhakedath, J. Antony, B. Francis, P. S. S. Anand, A. Radhakrishnapillai, C. Lalramchhani, S. Kannappan, R. D. Marimuthu, et al. (2022). Production of Juvenile Mud Crabs, *Scylla serrata*: Captive Breeding, Larviculture and Nursery Production. *Aquaculture Reports*, **22**; 101003

Pedapoli, S. and K. R. Ramudu (2014). Effect of Water Quality Parameters on Growth and Survivability of Mud Crab (*Scylla tranquebarica*) in Grow Out Culture at Kakinada Coast, Andhra Pradesh. *International Journal of Fisheries and Aquatic Studies*, **2**(2); 163–166

Rizk, R., T. Juzsakova, M. B. Ali, M. A. Rawash, E. Domokos, A. Hedfi, M. Almalki, F. Boufahja, H. M. Shafik, and Á. Rédey (2022). Comprehensive Environmental Assessment of Heavy Metal Contamination of Surface Water, Sediments and *Nile tilapia* in Lake Nasser, Egypt. *Journal of King Saud University-Science*, **34**(1); 101748

Rozirwan, R., F. Fauziyah, R. Y. Nugroho, M. Melki, T. Z. Ulqodry, F. Agustriani, E. N. Ningsih, W. A. E. Putri, A. Absori, and M. Iqbal (2022). An Ecological Assessment of Crab's Diversity among Habitats of Migratory Birds at Berbak-Sembilang National Park Indonesia. *International Journal of Conservation Science*, **13**(3); 961–972

Saputra, A., R. Nugroho, R. Isnaini, and Rozirwan (2021). A Review: The Potential of Microalgae as a Marine Food Alternative in Banyuasin Estuary, South Sumatra, Indonesia. *Egyptian Journal of Aquatic Biology and Fisheries*, **25**(2); 1053–1065

Selvi, A., A. Rajasekar, J. Theerthagiri, A. Ananthaselvam, K. Sathishkumar, J. Madhavan, and P. K. Rahman (2019). Integrated Remediation Processes toward Heavy Metal Removal/recovery from Various Environments-A Review. *Frontiers in Environmental Science*, **7**; 66

Shrestha, R., S. Ban, S. Devkota, S. Sharma, R. Joshi, A. P. Tiwari, H. Y. Kim, and M. K. Joshi (2021). Technological Trends in Heavy Metals Removal from Industrial Wastewater: A Review. *Journal of Environmental Chemical Engineering*, **9**(4); 105688

Soegianto, A., H. I. Wahyuni, B. Yulianto, and L. Abd Manaf (2022). Health Risk Assessment of Metals in Mud Crab (*Scylla serrata*) from the East Java Estuaries of Indonesia. *Environmental Toxicology and Pharmacology*, **90**; 103810

Upadhyay, R. K. (2020). Markers for Global Climate Change and Its Impact on Social, Biological and Ecological Systems: A Review. *American Journal of Climate Change*, **9**(03); 159

Ustaoğlu, F., Y. Tepe, and B. Taş (2020). Assessment of Stream Quality and Health Risk in a Subtropical Turkey River System: A Combined Approach Using Statistical Analysis and Water Quality Index. *Ecological Indicators*, **113**; 105815

Whitehead, P., G. Bussi, R. Peters, M. Hossain, L. Softley, S. Shawal, L. Jin, C. Rampley, P. Holdship, and R. Hope (2019). Modelling Heavy Metals in the Buriganga River System, Dhaka, Bangladesh: Impacts of Tannery Pollution Control. *Science of the Total Environment*, **697**; 134090

Yan, H., H. Zhang, Y. Shi, Z. Ping, L. Huan, D. Wu, and L. Liu (2021). Simulation on Release of Heavy Metals Cd and Pb in Sediments. *Transactions of Nonferrous Metals Society of China*, **31**(1); 277–287

Yogeshwaran, A., K. Gayathiri, T. Muralisankar, V. Gayathri, J. I. Monica, R. Rajaram, K. Marimuthu, and P. S. Bhavan (2020). Bioaccumulation of Heavy Metals, Antioxidants, and Metabolic Enzymes in the Crab *Scylla serrata* from Different Regions of Tuticorin, Southeast Coast of India. *Marine Pollution Bulletin*, **158**; 111443

Zhang, M., X. Sun, Y. Hu, G. Chen, and J. Xu (2022a). The Influence of Anthropogenic Activities on Heavy Metal Pollution of Estuary Sediment from the Coastal East China Sea in the Past Nearly 50 Years. *Marine Pollution Bulletin*, **181**; 113872

Zhang, Y., C. Lin, B. Li, Y. Cheng, W. Xu, Y. Xiao, D. Chen, W. Dong, and M. Shu (2022b). The Health Risk for Consumers under Heavy Metal Scenarios: Reduce Bioaccumulation of Cd in Estuary Mud Crab (*Scylla paramamosain*) through the Antagonism of Se. *Science of The Total Environment*, **844**; 157149

Zhang, Z., Z. Fang, J. Li, T. Sui, L. Lin, and X. Xu (2019). Copper, Zinc, Manganese, Cadmium and Chromium in Crabs from the Mangrove Wetlands in Qi'ao Island, South China: Levels, Bioaccumulation and Dietary Exposure. *Watershed Ecology and the Environment*, **1**; 26–32

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COVER LETTER

Indralaya, June 26, 2023

To: **Prof. Aldes Lesbani, Ph.D**
Editor in Chief
Science and Technology Indonesia

Dear Prof.,

I wish to submit an original research article entitled "**An Assessment of Heavy Metal Pollution in Waters, Sediments, and Mud Crabs (*Scylla Serrata*) from Mangrove Ecosystem Near Tanjung Api-Api Port Area, South Sumatra, Indonesia**" for consideration by *Science and Technology Indonesia.* I confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

In this paper, we report on / show that the assessment of heavy metal in waters, sediment, and mud crabs from mangrove ecosystem near Tanjung Api-api Port. Heavy metal accumulation in sediment and mud crabs has not exceeded the quality standard. It will be still good and safe for the human consumption based on consumption per week index. We believe that this manuscript is appropriate for publication by *Science and Technology Indonesia* because it is a natural science related to the assessment the level of heavy metal pollution in environmental chemistry.

We have no conflicts of interest to disclose in regard to this research or its funding. All authors have read and approved the manuscript and take full responsibility for its content.

Please address all correspondence concerning this manuscript to me at email:
rozirwan@unsri.ac.id

The email of all authors:

Rozirwan	rozirwan@unsri.ac.id
Aning Puji Saputri	aningps13@gmail.com
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Fauziyah	fauziyah@unsri.ac.id

Thank you for your consideration of this manuscript.

Sincerely,

Dr. Rozirwan
Department of Marine Science
Faculty of Mathematics and Natural Sciences
Sriwijaya University, South Sumatra 30862, Indonesia
Phone: +62 81371711885, Email: rozirwan@unsri.ac.id

Rozirwan unsri <rozirwan@unsri.ac.id>

[STI] Submission Acknowledgement

1 pesan

Prof. Aldes Lesbani, Ph.D <scitechindones@gmail.com> 26 Juni 2023 pukul 15.43
Kepada: "Dr.Rozirwan, S.Pi., M.Sc." <rozirwan@unsri.ac.id>

Dear Dr.Rozirwan, S.Pi., M.Sc.:

Thank you for submitting your manuscript entitled "An Assessment of Heavy Metal Pollution in Waters, Sediments, and Mud Crabs (Scylla Serrata) from Mangrove Ecosystem Near Tanjung Api-Api Port Area, South Sumatra, Indonesia" to Science and Technology Indonesia. Now, your manuscript will be considered by the editor and section editor before further peer-review process. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal website:

Submission URL: https://sciencetechindonesia.com/index.php/jsti/authorDashboard/submission/828
Username: rozirwan

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

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Rozirwan unsri <rozirwan@unsri.ac.id>

[STI] Editor Decision

1 pesan

Prof. Aldes Lesbani <scitechindones@gmail.com> 31 Juli 2023 pukul 12.12
Kepada: "Dr.Rozirwan, S.Pi., M.Sc." <rozirwan@unsri.ac.id>, Aning Puji Saputri <aningps13@gmail.com>, Redho Yoga Nugroho <redhoyn.29@gmail.com>, Nadila Nur Khotimah <nadilakhotimah1142@gmail.com>, Wike Ayu Eka Putri <wike_ayu_ep@unsri.ac.id>, Fauziyah <siti_fauziyah@yahoo.com>, Anna Ida Sunaryo Purwiyanto <anna.ida3@gmail.com>

Dear Dr.Rozirwan, S.Pi., M.Sc., Aning Puji Saputri, Redho Yoga Nugroho, Nadila Nur Khotimah, Wike Ayu Eka Putri, Fauziyah, Anna Ida Sunaryo Purwiyanto:

Reviewers have now commented on your paper (attached below this email). You will see that they are advising that you must revise your manuscript. If you are prepared to undertake the work required, I would be pleased to reconsider my decision.

For your guidance, reviewers' comments can be read in your Author online interface. If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript.

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Thank you for submitting to this journal.

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[STI] Editor Decision

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Prof. Aldes Lesbani <scitechindones@gmail.com> 4 September 2023 pukul 13.28
Kepada: Rozirwan <rozirwan@unsri.ac.id>, Aning Puji Saputri <aningps13@gmail.com>, Redho Yoga Nugroho <redhoyn.29@gmail.com>, Nadila Nur Khotimah <nadilakhotimah1142@gmail.com>, Wike Ayu Eka Putri <wike_ayu_ep@unsri.ac.id>, Fauziyah <siti_fauziyah@yahoo.com>, Anna Ida Sunaryo Purwiyanto <anna.ida3@gmail.com>

Dear Rozirwan, Aning Puji Saputri, Redho Yoga Nugroho, Nadila Nur Khotimah, Wike Ayu Eka Putri, Fauziyah, Anna Ida Sunaryo Purwiyanto:

Your article "An Assessment of Pb and Cu in Waters, Sediments, and Mud Crabs (Scylla serrata) from Mangrove Ecosystem Near Tanjung Api-Api Port Area, South Sumatra, Indonesia," is has been pre-published in upcoming issue.

URL of the issue in progress is here: https://sciencetechindonesia.com/index.php/jsti/

Thank you for your great contribution.

Best regards

Science and Technology Indonesia

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Response to Reviewers

Reviewer #A	**Response to Reviewer**
Title	
“Heavy Metal Pollution” change to “Pb and Cu”	We have revised it
Abstrack	
Add “which is”	We have added it
“value” to “values”	We have fixed it
Which one that the high quality ? Please describe your base opinion?	MWI and MIT are the main indicators to assess the safety level of biota consumption. In this study, the MWI and MIT values were in the safe category or it meant that *S. serrata* still had high quality for human consumption.
Introduction	
Is it true base on the economic development? How much economic growth in this area per year within last 5 years? “*rapid economic development*”	Based on the direct and indirect impacts, that economic growth contributes to an increase in anthropogenic activity. From the growing anthropogenic activities, it causes the potential for waste to pollute the environment, especially urban rivers, in this case, namely the Musi River. The area was urban river in Palembang City which has 5-6% economic growth per year.
What subject of it? “*they are*”	We have corrected it becomes “it has”
Experimental Section	
Why it is not filtered to remove the organic matters prior adding the acid? “*prevent changes in organic matter by bacterial activity and transferred in an ice box*”	Procedurally, the water sample is filtered after the organic matter destruction process by adding acid. We explained that at the beginning of the paragraph sub-chapter 2.4.
“Is that 100% sure, the blade of blender didn’t containing any of Pb or Cu?”	Yes, the blade was made from a stainless-steel scalpel so it protected more from contamination
Results and Discussion	
Since this is environmental data, what is your percent confidence level in this data? “*Table 1*”	confidence level 95%
What is your reason for comparing the pH parameters in the study area with the pH of fresh water?	The pH of the waters is affected by salinity. Sea water has a salinity of 30-35 ‰ which causes the pH to become more alkaline (> 7). Meanwhile, the pH of fresh waters tends to be more acidic

	(<7) causing the salinity level to decrease to even zero. This theory states that the pH of the estuarine waters in this study tends to approach the pH of fresh waters, this is due to the fluctuating dynamics of the estuary.
Please attach calibration data of those parameters, in separate files	Attached
Please explain how did you get this data while the sediment being analyzed is in wet condition, and again the confidence's of your data? "*Table 2*"	There were two ways to analyze the grain size of sediments, the dry method and the wet method. By estimating clay sediment samples, the wet method was more appropriate to use. The procedure would be sieved in stages until it reached the smallest sieve mesh size (2 mm to 0.0625 mm). The wet method served to maximize the sieving process because dry sediment was prone to flying in the air.
Please attach data validation from the method that has been used! "*detected (nd)*"	Attached
Please add the appropriate units "*Table 3*"	We have added the units
Please add the error bar in this graft "*Figure 4*"	We have edited the graph to adding the error bar
Reviewer #B	
Please add more literatures in introduction to see the novelty of your research in this article	We have added it
Please aslo compare the results of other places that also analyzed heavy metal content on *S.serrata* or other crab and their species	We have added it
Please use statistic analysis to see is there any different between each location for your results rergarding heavy metal content	We have added it

Rozirwan unsri <rozirwan@unsri.ac.id>

Request Revisions_Round 2 (STI-828)

4 pesan

Aldes Lesbani <sciencetechindonesia@gmail.com> 15 Agustus 2023 pukul 10.42
Kepada: rozirwan@unsri.ac.id

Dear Author,

We have checked your revised article and there are still parts that you need to revise. Please revise your article based on the comments below:

i) Please check Figure 3, there are parts that are cut off, please revise and improve the image quality.
ii) Please revise Figures 4, 5, and 6 based on the journal format (see the article template on the website). Outline on the figure is just 1, no need to double and no need for lines on the background of the graph.

Please submit your article before August 23, 2023. Thank you.

Sincerely Yours,

Editor-in-Chief
Prof. Aldes Lesbani, Ph.D.
Science & Technology Indonesia
http://sciencetechindonesia.com

Rozirwan unsri <rozirwan@unsri.ac.id> 18 Agustus 2023 pukul 09.24
Kepada: Aldes Lesbani <sciencetechindonesia@gmail.com>

Dear Editor

Here, we would like to resubmit our revised article based on your comments above.

Thank you
Warm regards
[Kutipan teks disembunyikan]
--
Dr. Rozirwan
Head of Marine Bioecology Laboratory
Department of Marine Science
Faculty of Mathematics and Natural Sciences
Sriwijaya University

Jalan Raya Palembang-Prabumulih KM 32, Indralaya
Ogan Ilir, Sumatera Selatan, Indonesia, Pos Code: 30862
Email: rozirwan@unsri.ac.id, rozirwan@gmail.com

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Aldes Lesbani <sciencetechindonesia@gmail.com> 21 Agustus 2023 pukul 13.26
Kepada: Rozirwan unsri <rozirwan@unsri.ac.id>

Dear Author,

we have checked your article, but there is still something to be revised in the image section which we attach to the following word file.

Please submit your article before August 24, 2023. Thank you.

Sincerely Yours,

Editor-in-Chief
Prof. Aldes Lesbani, Ph.D.
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Rozirwan unsri <rozirwan@unsri.ac.id> 21 Agustus 2023 pukul 15.17
Kepada: Aldes Lesbani <sciencetechindonesia@gmail.com>

Dear Editor

Here, we would like to resubmit our revised article based on your comments in the image sections.

Thank you
Kind regards
[Kutipan teks disembunyikan]

Rozirwan unsri <rozirwan@unsri.ac.id>

[STI] Editor Decision

1 pesan

Prof. Aldes Lesbani <scitechindones@gmail.com> 22 Agustus 2023 pukul 11.17

Kepada: "Dr.Rozirwan, S.Pi., M.Sc." <rozirwan@unsri.ac.id>, Aning Puji Saputri <aningps13@gmail.com>, Redho Yoga Nugroho <redhoyn.29@gmail.com>, Nadila Nur Khotimah <nadilakhotimah1142@gmail.com>, Wike Ayu Eka Putri <wike_ayu_ep@unsri.ac.id>, Fauziyah <siti_fauziyah@yahoo.com>, Anna Ida Sunaryo Purwiyanto <anna.ida3@gmail.com>

Dear Dr.Rozirwan, S.Pi., M.Sc., Aning Puji Saputri, Redho Yoga Nugroho, Nadila Nur Khotimah, Wike Ayu Eka Putri, Fauziyah, Anna Ida Sunaryo Purwiyanto:

We have reached a decision regarding your submission to Science and Technology Indonesia, "An Assessment of Heavy Metal Pollution in Waters, Sediments, and Mud Crabs (Scylla Serrata) from Mangrove Ecosystem Near Tanjung Api-Api Port Area, South Sumatra, Indonesia".

Our decision is to accept your submitted manuscript for publication in

Thank you for publishing with us and please do not hesitate to contact us if you have any inquiry.

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Proofread and Invoice Article (STI-828)

3 pesan

Aldes Lesbani <sciencetechindonesia@gmail.com> 3 September 2023 pukul 22.52
Kepada: Rozirwan unsri <rozirwan@unsri.ac.id>

Dear Author,

I am sending the proof of the manuscript for your approval and final check before publishing it in Science and Technology Indonesia. If anything needs to be changed, please inform us as soon as possible.

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Rozirwan unsri <rozirwan@unsri.ac.id> 4 September 2023 pukul 06.02
Kepada: Aldes Lesbani <sciencetechindonesia@gmail.com>

Dear Editor,

We have checked the manuscript and we would like to attach the invoice of the publication fee 3,700,000 IDR

Thank you
Regards
[Kutipan teks disembunyikan]
--
Dr. Rozirwan
Head of Marine Bioecology Laboratory
Department of Marine Science
Faculty of Mathematics and Natural Sciences
Sriwijaya University
Jalan Raya Palembang-Prabumulih KM 32, Indralaya
Ogan Ilir, Sumatera Selatan, Indonesia, Pos Code: 30862
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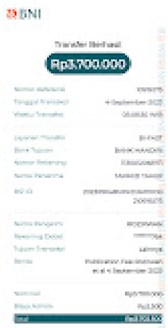
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Aldes Lesbani <sciencetechindonesia@gmail.com> 4 September 2023 pukul 13.31
Kepada: Rozirwan unsri <rozirwan@unsri.ac.id>

Dear Author,

We have received your publication fee, please find the attached file. Your article has been included in the Upcoming Issue section. Thank you for your cooperation.

Sincerely Yours,

KOMUNITAS BENTIK

UPAYA PENINGKATAN NILAI TAMBAH EKOSISTEM

Dr. Rozirwan, S.Pi., M.Sc.
Prof. Dr. Fauziyah, S.Pi.
Dr. Wike Ayu Eka Putri, S.Pi., M.Si.

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