Characteristics of hydro-oceanography in the Aceh waters, Indonesia: expedition by R/V Baruna Jaya IV

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Abstract. Aceh waters, one of the largest sea region in Indonesia, is believed to hold the greatest potential of marine and fisheries resources. The present paper aims to conduct seawater samplings by means of stationery as well as underway survey operated by R/V Baruna Jaya IV. The result showed that four types of water masses were identified for each layers and salt-lens structure covering 60 miles in diameter and 25 meters in thickness, with core salinity is greater than 35 psu was detected at 75-100 meters depth across the thermocline layer in the Northern Weh Island. This salinity front could be an early detection to the occurrence of upwelling phenomenon and have a close potential on the existence of pelagic fish. This finding brings benefit towards future marine resources development in Aceh, Indonesia.

Key Words: thermocline layer, salinity front, upwelling.

Introduction. Geographically Aceh Province border vast Indian Ocean, Strait of Malacca, Andaman Sea in the West, East, and North, respectively. It leads the coastline across the Province may reaches 1,680 km, or about 2.1% of the length of coastline in Indonesia. The Aceh Waters itself is located in the eastern part of the Indian Ocean in regions of low geographical lattitude at 94°30' - 98°05' E and 01°45' - 06°50' N (Irham & Setiawan 2017; Irham et al 2017).

Two reversal circulation, i.e., northeast and southwest monsoon play a major role in bringing wet and dry condition during December-February and June-August over the region, respectively (Ramage 1971; Unger et al 2003; Diansky et al 2006). The monsoonal system also plays a major role in driving the water mass in the ocean, impacting temperature, salinity, and density as well as sediment (Purnawan et al 2015; Purnawan et al 2016; Purnawan et al 2018a, 2018b, 2018c). Another influencing factors, e.g., high river discharge flowing into the ocean and strong rainfall variability are local factors that impact water mass mixing in this seawater region (Wyrtki 1961; Ilhamsyah 2013; Ilhamsyah et al 2014).

Geographically, the Aceh Waters become the gateway of the world's sea routes. Vast sea area bring the Aceh Waters to have such great potential in marine. However, the utilization of marine resources in the Aceh waters is still less, due to lack of research activities that specifically assessing the potential of Aceh's marine resources. One of the supporting inputs for managing marine resources is by integrating many disciplines to support sustainable research activities of the Aceh Waters sector (Rizal 2000; Rizal 2002; Haridhi et al 2016).

The Government of Indonesia under responsible department address these issues by implementing the oceanographic survey, so-called "the assessment of potential of

Aceh's marine resources" by R/V Baruna Jaya IV which was coordinated by UPT Baruna Jaya BPPT (Agency for the Assessment and Application of Technology-Indonesia). The objective of the survey is to collect physical parameters of seawater that would be useful to support sustainable utilization of Aceh's marine resources. The targets in this survey are: collecting integrated physical parameters of temperature, salinity, and density; developing a better understanding on the interaction of physical properties of seawater to the water column and pressure, thus, the process of water mass movement leading to upwelling is well-observed which further bring benefit on the detection potential of fishery resources spot in Aceh.

Material and Method

Survey methodology. The research activities were conducted onboard the R/V Baruna Jaya IV. R/V Baruna Jaya is operated under management team of BPPT that is responsible for managing and maintaining research vessel to support research activities in the field of Marine Technology. The specification of the ship are as follows:
- length: 60.40 m;
- length in the water line: 55.68 m;
- length between vertical lines: 55.25 m;
- width: 12.10 m;
- upper deck height: 6.5 m;
- main deck height: 4.2 m;
- total crews: 59 people.

Stationary survey, a survey method that would be conducted at a pre-defined observation station, was used during expedition. As many as 41 sampling stations are specified in the Aceh Waters (Figure 1).

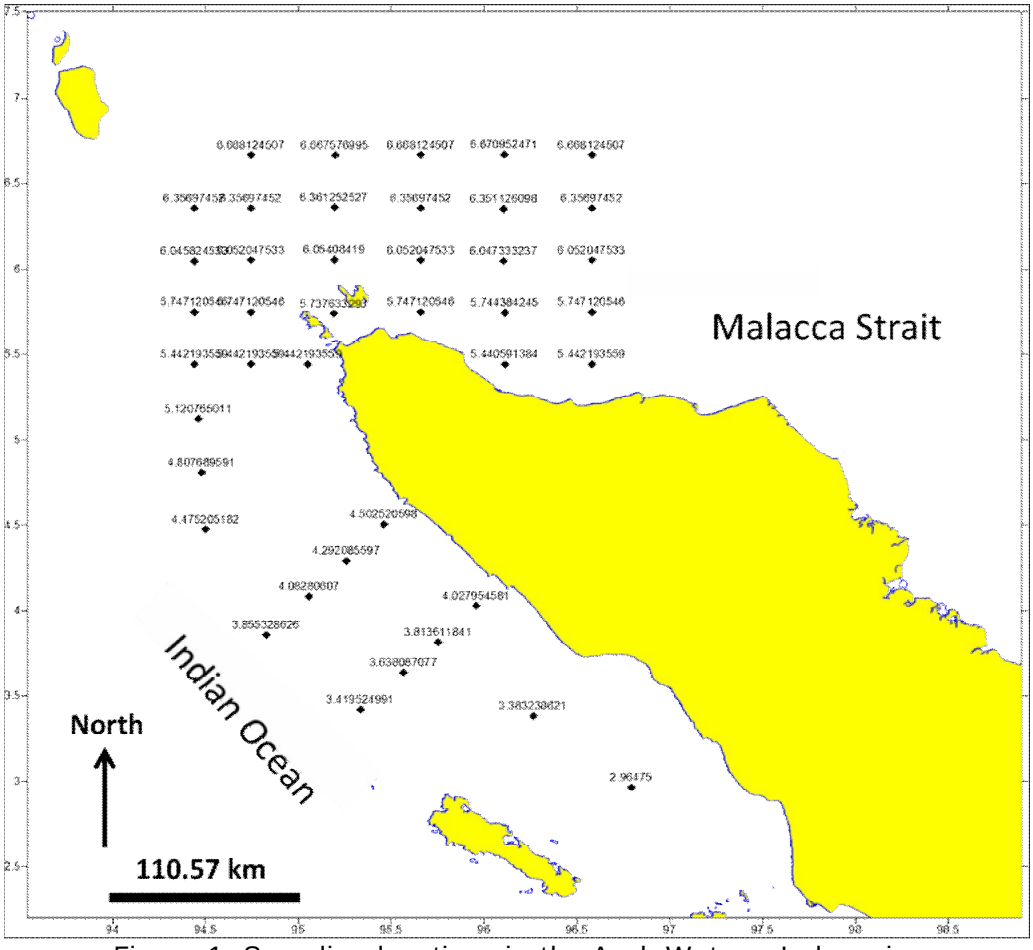

Figure 1. Sampling locations in the Aceh Waters, Indonesia.

Direct measurement by using particular instrumentation/sensor and seawater sampling were collected at all stations. The samplings were analyzed further at onboard-laboratory. The underway survey, observation without a ship stop at a certain position or continous data acquisition recording along the track, is also carried out. The collecting data includes the likes of navigation, bathymetry, acoustic, and currents profile/ADCP. The expedition lasted for two weeks from October 28th, 2002 to November 05th, 2002 during northeast monsoon under normal ocean condition despite punctuated with rain at particular days. Since offshore research require high expenses, the validity of the data collected during 2002 marine survey are still accounted for. It is noted that the data is highly demanded since the oceanographical characteristics over the region are still poorly-understood. For this, BPPT manage an online webpage under oceanographic data to publish all survey sampling data throughout Indonesia that can be accessed at http://bpptbuoy.info/pdbi/metocean/index.php?id=14.

Navigation and sounding. Positioning and navigation are a series of activities to determine the integrated position of the ship and sampling location. Positioning is tracked by GPS (Global Positioning System) satellite measurements. The GPS receiver used in this survey was the Garmin 12 XL and SERCEL NR 103 where the output position of this receiver is used as input to the integrated navigation system, i.e., the NavREC system. This NavREC system is an integrated on-line and digital system developed by UPT Baruna Jaya-BPPT for navigating and recording the water depths. Ocean depth data is digitally obtained from SIMRAD EK-500 and integrated into the NavREC system as sounding data. For deep sea water, the sounding is operated manually by using 3.5 KHz frequency of transceiver Sub-Bottom Profiler ORETECH 3010, equipped with a paper recorder LAZ 4700. The marking of time on a recording paper is conducted regularly to determine the position of the navigation record based on time synchronization principle.

Current field observation. The profiles of currents were recorded by using ADCP (Acoustic Doppler Current Profiler). ADCP instrument turned on since R/V Baruna Jaya IV departed from Tanjung Priok Port, Jakarta, Indonesia. ADCP has been set up to measure the averaged currents in every 5 minutes. The current depth column was recorded every 5 meters interval, with the first column being detected at 15 meters.

Measurement of temperature and salinity profiles. Seawater samplings were measured at specified depth by lowering CTD Guildline 6000 sensor instrument consisting of 12 Niskin bottles. The CTD sampling was operated by the control unit model 87102A and stored digitally using Sukondal 2000 software. The sampling at certain depths, i.e., 1000, 750, 500, 300, 250, 200, 150, 125, 100, 75, 50 and 25 were controlled by using Rossete SUBER-RS 360. CTD measurement system consist of on-line CTD data acquisition unit onboard and the Frame unit consisting of CTD sensors and 12 Niskin bottles. Both are connected with a CTD winch cable. Schematically onboard CTD measurement system is shown at Figure 2. The salinity units retrieved from this system are the derived units of temperature, conductivity, and pressure with a practical salinity scale formulation recommended by UNESCO and later known as practical salinity scale 78 (Pond & Pickard 1983). The salinity and density distributions were calculated by using a set of seawater subroutines developed by Philip P. Morgan of CSIRO, Australia.

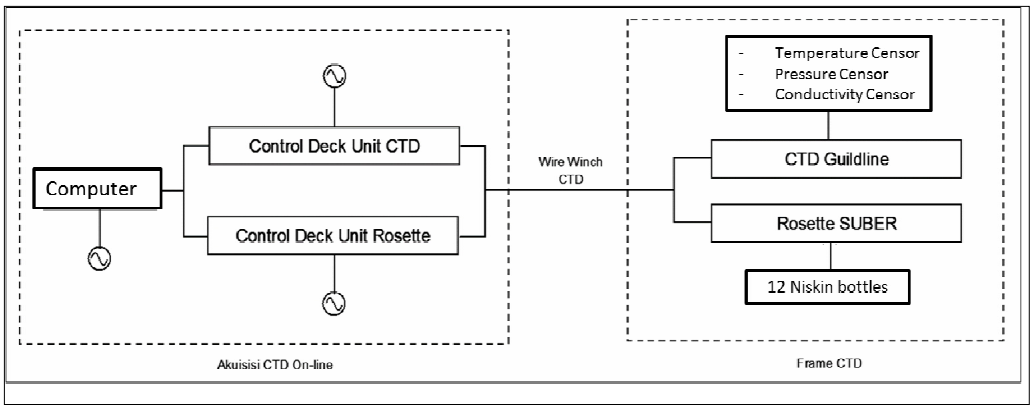

Figure 2. Schematic diagram of CTD measurement.

Results. R/V Baruna Jaya IV arrived at the survey location and began a bathimetric survey on October 28, 2002 at 15.00 local time. The entire track of the bathymetric survey is shown in Figure 1. Bathymetric survey lasted for 4 days with a total distance of 855 nautical miles, covered an area of 70,956 km^2. During the survey, the average speed of the vessel was 9-10 knots. The deepest and the shallowest depth were found more than 2500 meters and less than 200 meters, respectively. ADCP measurement began on October 28, 2002 at 15.00 local time. On October 30, 2002 at 22.05 local time, ADCP was unable to record navigation data derived from GPS Sercel NR103. This incident lasted for about 2 hours due to broken GPS SERCEL. After it is replaced with Garmin 12XL GPS, ADCP is back to normal. Similar to topographic sounding, 885 nautical miles was noted as total distance of ADCP measurement.

During survey we encountered several obstacles, the most important was the ability of the echosounder instrument of R/V Baruna Jaya IV. Echosounders are only able to transmit digital data to the Navrec system at a maximum depth of 500 meters. The deep sea echosounder installed on R/V Baruna Jaya IV was unable to transmit digital data to the Navrec system which makes the sounding was performed by using the echogram of the echosounder. Since recording was performed every 5 minute intervals, there have been many averaging and interpolation processes during data processing.

Discussion. From the bathymetric map, it is shown that the Aceh Waters are classified into deep waters where depths range from 400 to 2300 meters. The steepest slope is found at 95°E; 06°30'N, extends from north to south. The analysis of water masses characterized by temperature, salinity, and density per depth of the water column showed the presences of four water masses in the northern part of Aceh Waters as depicted by four typical Temperature and Salinity (TS) diagrams, as shown in Figure 3:

- the first type (number 1) is characterized by relatively low salinity in the thermocline layer where salinity and temperature increase and decrease monotonically with depth, respectively. This type is mostly found in the Malacca Strait, in the North Aceh Waters, and Pidie;
- the second type (number 2) is characterized by relatively low salinity in the thermocline, but traces of maximum salinity are found at depth between 75 m to 100 m. This type is found in the North Weh island;
- the third type (number 3) is characterized by water with high salinity in the thermocline with maximum-minimum pattern. This type is found in the West Weh Island;
- the fourth type (number 4) is characterized by relatively high salinity with monotonously increase with depth. This type is found in seawater between Simeulue Island and Sumatera.

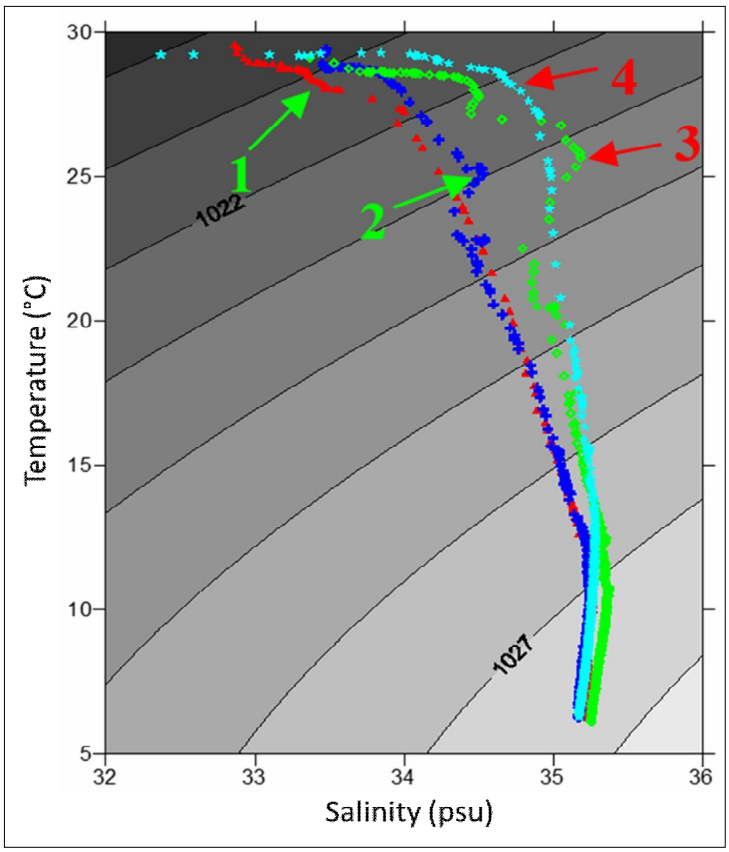

Figure 3. Characteristics of water mass in the Aceh Waters. Four typical TS Diagram as indicated by red, blue, green, and light blue colors.

It is also found salt-lens structure, lens-shaped water with maximum salinity in the North Weh Island (Figure 4b). The diameter of this structure is about 60 miles and 25 m in thickness with core salinity is greater than 35 psu. The whirl flowing at its axis at depths of 75-100 m was found. This whirlpool (circular water mass circulation) occurred clockwise leading to upwelling in the upper layer with relatively high salinity at surface (Figure 4a).

The characteristics of water mass and its vortex movement in the thermocline layer is proposed as a mechanism on the development of upwelling in this region and an early detection of fishing ground. This location of the salinity front leading to potential areas of upwelling is shown in Figure 4b. The existence of water mass front found in this region could be an indication of the presence of potential pelagic fish. Haridhi et al (2016) found the fishing ground that is located in the north based on surface temperature associated with fishing catch. The northern fishing ground is also revealed by Mursyidin et al (2015) who estimate surface temperature and chlorophyll-*a* observed from the satellite. However, a better understanding on the movement of spatial and temporal front pattern as well as water mass transport would be very helpful as an effective solution on fishing operations. It is expected that the large front region could be continously monitored, and modelling research could be addressed upon this issue as described by the latest research of Atmadipoera & Widyastuti (2014) in the eastern part of the Indonesian Seas.

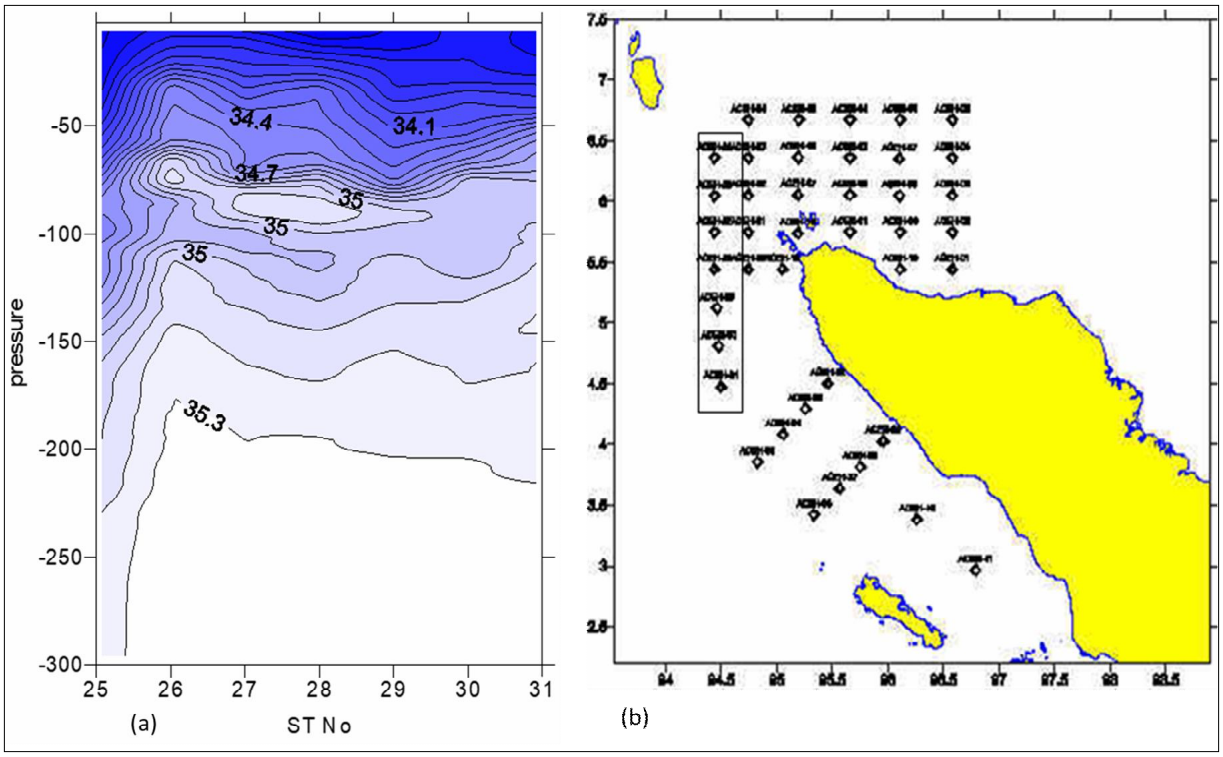

Figure 4. (a) Salt-lens structures (whirlpool), and (b) Location of the salinity front as depicted in the rectangle of North Aceh Waters.

A uniform flow pattern of currents coming from the Malacca Strait was found from a depth of 15 to 100 meters. The currents moved towards west and as it arrived around 95°30' E, it turned to the north. This currents partially passed through the north of Weh Island to latitude of 6°N and was found from 15 to 50 meters depth (Figure 5a).

In the northeast to the north of Weh Island, the currents originating from the west (Indian Ocean) moved eastward, as it met currents from the Malacca Strait, it turned northward while the rest turning back towards west. This situation was found at a depth of 15 to 65 meters. From such condition there was a potential of front occurrence in the north of Weh island around 95°20' E (Figure 5b).

The currents originating from the Indian Ocean in the west of Weh Island was partially deflected to the north as the rest is rotating when collided with currents flowing westward in the north of Weh Island. The current turns into clockwise eddy and was found to a depth of 80 meters (Figure 5c and 5d).

In the west of Aceh Province there was likely to occur a current front around 5°N between the currents originating from the south and from the north. In this location a uniform of current patterns was observed from 15 to 100 meters depth (Figures 5e, 5f). The current circulation recorded by ADCP is consistent with the works of Rizal et al (2010), Rizal et al (2012), Rizal et al (2013), and Setiawan et al (2018) who also investigate the current circulation in the Aceh Waters.

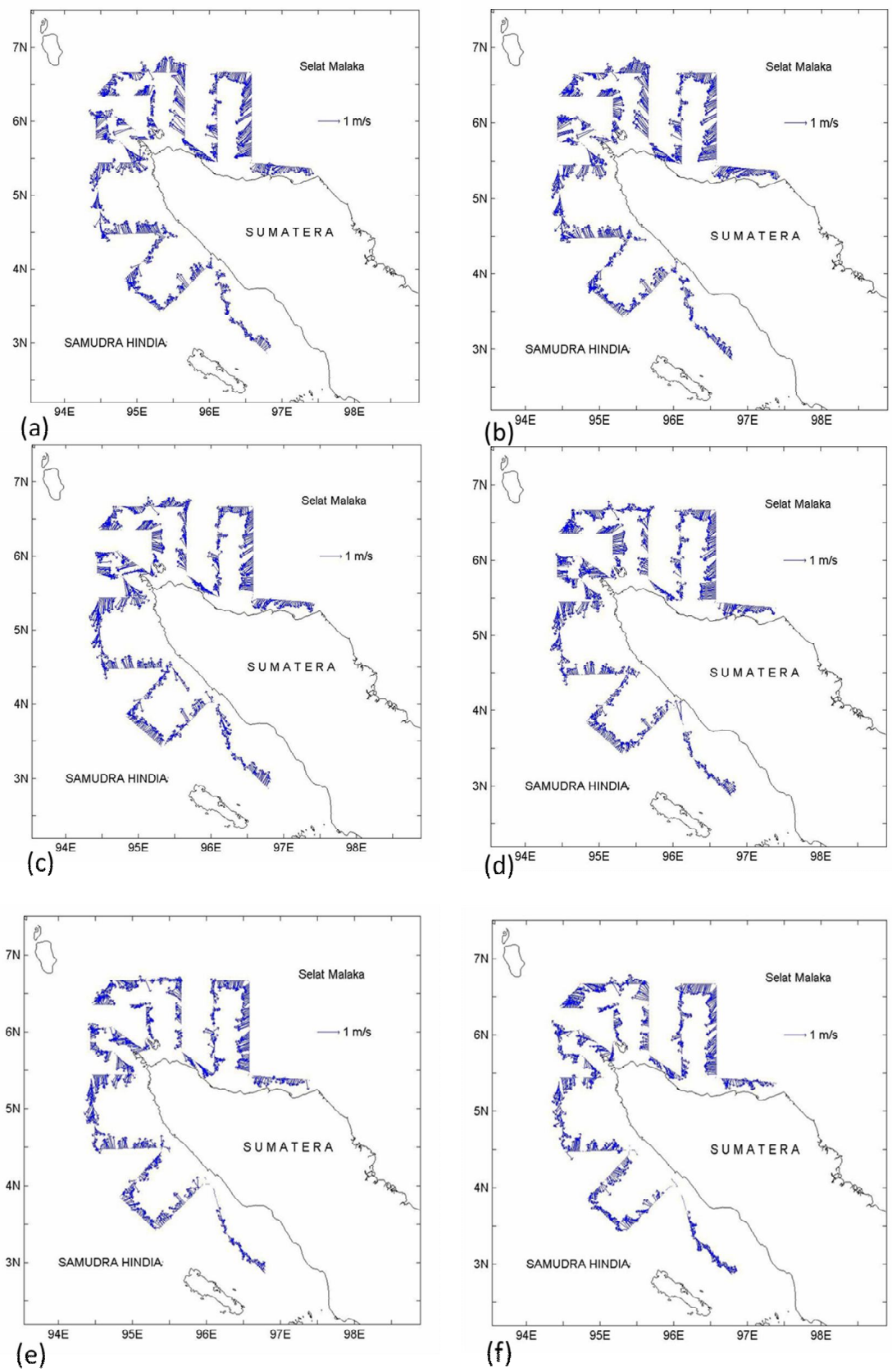

Figure 5. Current observation at a depth of (a) 15 m, (b) 30 m (c) 50 m (d) 65 m (e) 80 m (f) 100 m.

Conclusions. Four main characteristics of water masses were identified in the Aceh Waters. The existence of salinity front found in this region leading to upwelling could be an indication of the presence of potential pelagic fish. However, a better understanding on the movement of spatial and temporal front pattern as well as water mass transport is still required to achieve an effective solution on fishing operations. It is expected that the large front region could be continously monitored, and modelling research or remote sensing could be employed to address these issues.

Acknowledgements. The first author expresses gratitude and appreciation to Ir. Bambang Herunadi as onboard Chief Scientist at Baruna Jaya IV, Ir. Adi Slamet Riadi as research assistant. The expedition was part of The Project for the Development of Maritime and Aerospace Engineering Indonesia. The first author also would like to thank the Directorate of Research, Technology, and Community Service, Indonesian Ministry of Research, Technology, and Higher Education for providing publication fee under '*Penelitian Disertasi Doktor* (Doctoral Thesis Research Grant)' with contract number: 29/UN11.2/PP/SP3/2018.

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Received: 18 September 2018. Accepted: 29 October 2018. Published online: 15 December 2018.
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How to cite this article:
Ilhamsyah Y., Koesmaryono Y., Hidayat R., Nurjaya I. W., Atmadipoera A. S., Rizal S., 2018 Characteristics of hydro-oceanography in the Aceh waters, Indonesia: expedition by R/V Baruna Jaya IV. AES Bioflux 10(3):200-208.